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DEPARTMENT OF COMMERCE

BUREAU OF FISHERIES

HUGH M. SMITH, Commissioner

THE MUSSELS OF THE CUMBERLAND RIVER AND ITS TRIBUTARIES

By CHARLES B. WILSON and H. WALTON CLARK

Bureau of Fisheries Document No. 781

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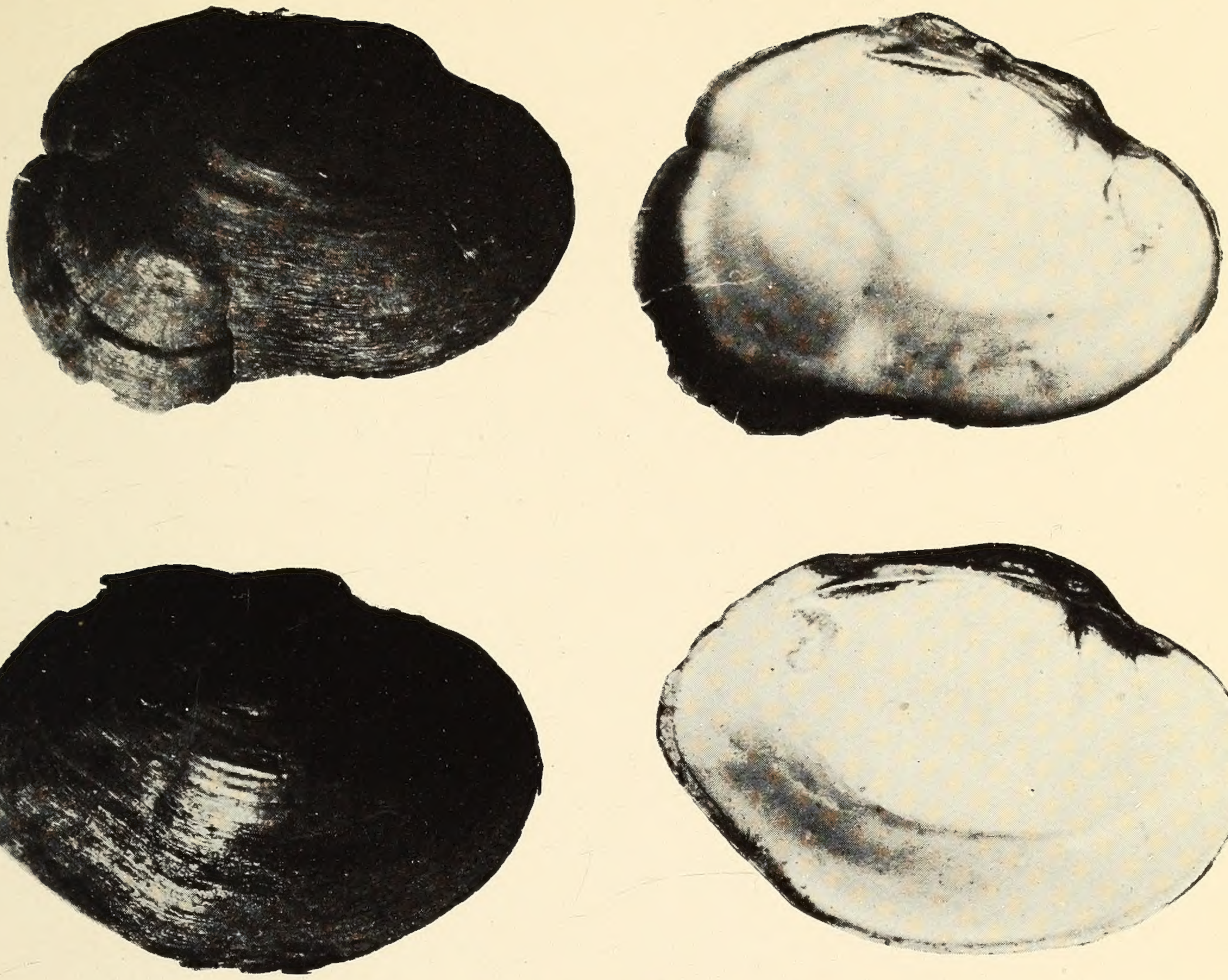

FIG. 1.—TRUNCILLA WALKERI, NEW SPECIES.

Upper figures, females; lower figures, males.

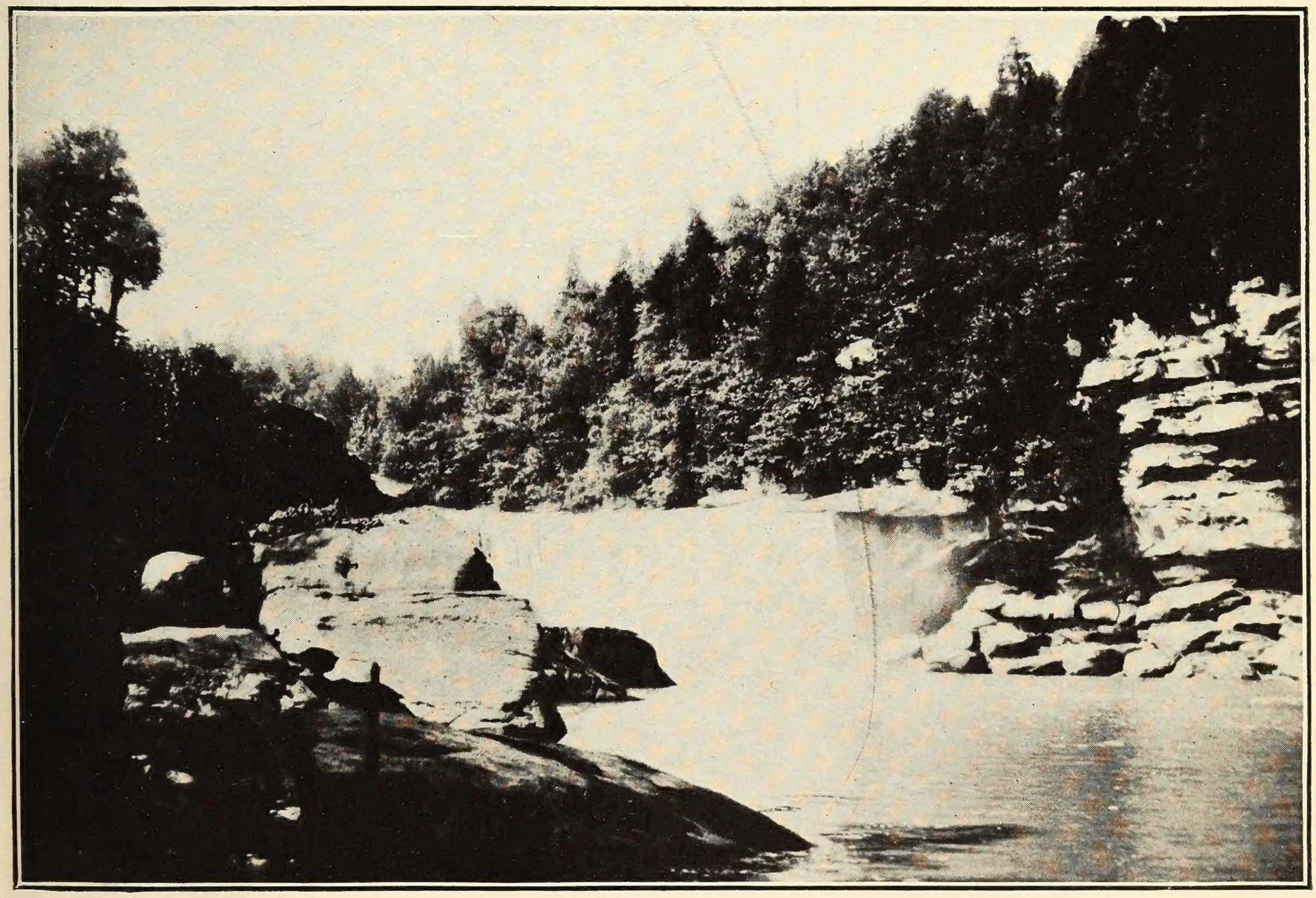

FIG. 2.—THE GREAT FALLS OF THE CUMBERLAND, 85 FEET HIGH, A BARRIER TO THE ASCENT OF FISH AND MUSSELS.

THE MUSSELS OF THE CUMBERLAND RIVER AND ITS TRIBUTARIES.

By Charles B. Wilson and H. Walton Clark.

INTRODUCTORY.

The purpose of this investigation was to ascertain the distribution, relative abundance, and habits of the various mussel species living in the river and its tributaries, and to make an intelligent appraisal of the mussel resources of the river from a commercial standpoint.

The party was under the supervision of Dr. Robert E. Coker, director of the United States Biological Station at Fairport, Iowa, who furnished general instructions to be used by all field parties engaged in mussel investigations. In addition to the authors, the party included the late Mr. J. F. Boepple, the shell expert of the Fairport station, and Mr. Ernest Danglade, now scientific assistant in the Bureau of Fisheries, each of whom contributed fully as much as either of the authors to the success of the investigations.

The work was begun about May 10 near the mouth of the Cumberland River, and conducted thence upstream through the State of Kentucky and into Tennessee as far as Clarksville. During the previous year it had been carried from Pineville, Ky., to Celina, Tenn. Accordingly, it was now resumed at Celina, where the Obey River, a tributary of the Cumberland from the south, was investigated. Thence the work continued slowly down the Cumberland itself.

From Jellico, Tenn., and Williamsburg, Savoy, Corbin, Livingston, and Barbourville, Ky., as centers, the upper portions of the Cumberland River, the Clear Fork, Big South Fork, Laurel and Rock Castle Rivers were examined. Neither the main river nor any of these tributaries is navigable for a boat, so that the investigations had to be conducted by team, driving along the banks or visiting convenient fords and shallows.

The party then drove by team from Williamsburg to the Cumberland Falls, proceeded again by team from the falls to Parkers Lake station, and thence by rail to Burnside, Ky. This is the head of steamboat navigation on the river, and here a small boat was constructed in which to proceed down the main river, thus completing the survey of the entire river.

During all these investigations the methods followed by the two divisions of the party were made as different as possible in order to cover the field more thoroughly. Mr. Boepple used the crowfoot dredge, tongs, and mussel rake, and worked the deeper portions of the river. The rest of the party covered the shallower water, riffles, sand bars, and smaller tributaries, and, of course, obtained the mussels by wading.

A careful record was kept of the temperature of the water at the various stations, and as often as seemed advisable samples were taken for subsequent analysis.

In addition to making original observations the party secured as much information as could be obtained from local fishermen and clammers with reference to the location of the mussel beds, past and present operations upon them, and the finding of pearls and baroques.

For such information we are particularly indebted to the following persons: Mr. Walter, of Dover, Tenn., an extensive dealer in shells; Mr. Samuel Dabbs, a clammer of Dover; Mr. M. K. Clark, proprietor of the blank factory at Clarksville, Tenn.; and Mr. Cicero Harris, a boatman who had floated down from the upper part of the river fishing and clamming, and who knew the river more intimately than anyone else it was our fortune to meet. To these gentlemen as well as to many others who extended favors and assistance whenever opportunity offered, our sincere thanks are tendered.

As fast as they were obtained, the samples of water and specimens were shipped to the biological station at Fairport. The shells were subsequently identified and studied by the principal author with the results herein set forth.

THE CUMBERLAND RIVER.

GENERAL DESCRIPTION.

The main branch of the Cumberland River rises among the foothills of the Pine Mountains, in the southeastern corner of Kentucky. It flows southwest along the eastern side of the mountains, receiving many tributaries. Near Pineville it turns at a right angle and flows northwest through a wide gap in the mountains, and then swings to the south, its general course being that of a half circle, convex toward the north. At State Line, in Monroe County, it crosses into Tennessee, its general course in the latter State being also that of a half circle but convex toward the south.

At Tobaccoport, in Stewart County, it crosses the State line back into Kentucky, flows northwest and enters the Ohio at Smithland, only 12 miles above the mouth of the Tennessee River at Paducah. The distance from the source to the mouth in a straight line is about 325 miles, but the river is so extremely crooked that its total length

is nearly 750 miles. Its principal tributaries are the Laurel and Rockcastle Rivers from the north, which join it within a few miles of each other at the southwestern corner of Laurel County, Ky.; the Big South Fork, whose mouth is at Burnside, Ky.; the Obey River from the south at Celina, Tenn.; Roaring River, from the south, at Gainesboro Landing, Tenn.; Caney Fork, from the south, at Carthage, Tenn.; Stones River, from the south, 15 miles above Nashville, Tenn.; Harpeth River, from the south, at Pardue, Tenn.; and the Red River, from the north, at Clarksville, Tenn.

The Cumberland is navigable during high water from its mouth to Burnside, Ky., a distance of 525 miles, and a system of locks is in process of construction which will make navigation possible during the entire year.

PHYSIOGRAPHY.

The area drained by the river and its tributaries is about 25,000 square miles, and embraces mountain ranges, a continental plateau (the Cumberland Plateau), and lowlands. Along the upper reaches of the river among the Cumberland and Pine Mountains in the eastern portion of the plateau the rocks are largely Cambrian sandstone; through the remainder of the plateau and the long stretch of lowlands they are almost universally limestone. The dividing line is at Cumberland Falls in the western part of Whitley County, Ky., where the river plunges over a wall 85 feet in height. From the source to the falls the river has nowhere cut its channel very deep; below the falls, and especially through the plateau, the banks are lined almost continuously with high limestone cliffs, filled with caves and roughly weathered. The faces of these cliffs furnish abundant evidence of past upheavals in numerous faults and contortions of the strata, as well as in repeated anticlinal and synclinal folds, differing considerably in intensity at different localities.

Above the falls the river valley is comparatively narrow, but below the falls it widens somewhat, and the river winds back and forth in broad and then in shorter curves, with cliffs now on one side and now on the other.

So evenly has the channel been worn down through the soft limestone that there are no rapids of any importance below the falls, and steamboats can run from the mouth up to Burnside in Pulaski County, Ky., within comparatively few miles of the falls, as already stated. This makes the river easy to navigate for two-thirds of its entire length, and since it runs through a great region remarkable for its mineral and agricultural resources and its large forests, but with a physical contour which makes the building of railroads exceedingly expensive, the Cumberland is destined to be one of the most important commercial highways of the United States.

COMPARISON WITH MAUMEE AND KANKAKEE RIVERS.

Both the Maumee and Kankakee Rivers, which were examined by the present authors, are situated in regions profoundly modified by the great glacier. In their basins the ice mass first removed the entire fauna and flora, and when it melted established new channels by which the river was restocked.

The Cumberland Valley presents an entirely different history. It is situated in a region which is geologically very old and which has not been much disturbed since its first upheaval, except by the ordinary forces of weathering and erosion and the subsequent formation of mountains. The Cumberland and Pine Mountains, as well as the great Cumberland Plateau, are portions of the Appalachian system, and the wrinkling which formed them took place toward the close of the Upper Silurian period. Originally very much higher than at the present day, they have gradually yielded to weathering and erosion, but are otherwise unchanged. The great glacier reached only a little below the Ohio River, which is far to the north of the Cumberland Valley.

CHARACTERISTICS OF THE MUSSEL FAUNA.

Consequently a primitive fauna and flora are to be looked for in this valley, one that began with the very origin of the valley itself, and has been gradually developing ever since without any serious disturbance; and in fact the best American authorities regard the Mississippi Valley as the original home of fresh-water mussels upon this continent, the rest of the rivers, ponds, and streams having been populated from this source. Some authorities even say that there is evidence to show that this fauna developed first in the New World and then spread to the Old World. However that may be, it is certain that the Mississippi area has the greatest diversity of species and the most magnificent shells to be found anywhere in the world.

The Cumberland and Tennessee Valleys are among the very oldest portions of the Mississippi region, and are commonly looked upon as the center of this wonderful mussel fauna. Accordingly we should expect to find in them a great diversity of species, some of which would be found nowhere else, and that such is the case has been well shown by many conchologists. Over 80 different forms of mussels have been reported from the Cumberland River, and the present examination has added 3 others. This is considerably more than twice the number found in the Maumee or the Kankakee River systems, and is a remarkably large representation compared with any river of equal size. A few of these species have never been reported from any other locality, but the great majority are common to the southern portion of the Mississippi system. Such of these as were found during the present examination are enumerated on pages 14 to 19.

GEOGRAPHIC DISTRIBUTION OF THE MUSSELS.

CONTRAST BETWEEN THE RIVER ABOVE AND BELOW THE FALLS.

The Cumberland Falls establish a natural barrier, dividing the river into an upper one-third and a lower two-thirds, between which there can be practically no interchange of animal life, and very radical differences appear in the mussel fauna. Above the falls only a very few species of mussels are found, and these are considerably dwarfed. *Unio gibbosus* is the only species in any abundance, and rarely one may find examples of *Lampsilis ovata*, *Alasmidonta minor*, and *Anodontoides ferussaciana*. This scarcity of species is as much due to the fact that all the conditions are unfavorable (see p. 23) as it is to the lack of intercourse past the falls, and in all probability there would be very little profit in stocking the river above the falls with mussels. Indeed we were told that some *Lampsilis ovata* were taken from below the falls and transplanted to the river above about seven years ago, with visible results, possibly, in the few dwarfed specimens of this mussel now present in the upper river.

In the river below the falls conditions are totally different. In the very pool at the base of the falls were obtained 19 species of mussels, all of them of normal size and perfectly healthy. And from this point down to the Ohio every portion of the river bed that is at all suitable for mussels is fairly covered with them.

Much of this part of the river has been thoroughly worked over by agents of the button factories, and the location, extent, and possibilities of the various beds are well known. Some clammers even have a memorandum list of the beds, giving the percentages of usable and useless shells in each. Many of these beds have been worked for some time, a few of them as long as 10 years, and an immense number of shells have been taken, as many as 200 to 300 tons from some of them. But in spite of the great number of mussels taken out, the river as a whole, according to general accounts, does not show any marked depletion except in one or two restricted localities. On the contrary, a comparison of many beds in the vicinity of Celina, Tenn., examined by Mr. Boepple in 1910 and again in 1911, showed a considerable increase. This was especially true of beds situated above the silt in the back water from the various lock dams. Such places seem peculiarly suited to rapid mussel growth, and furnish thereby a valuable suggestion as to the best localities for artificial propagation.

Of course the mussels that were too close to the dams, or that were in the mouth of tributaries filled with back water from the dams, would be killed by the increased deposit of silt, and the rise of water from behind the dams makes it harder to secure the mussels.

On the whole, however, the benefits seem greater than the disadvantages.

Incidentally it is worthy of note that the water privileges at Cumberland Falls have been leased to a company which has already begun operations toward establishing a power plant for furnishing electricity to Louisville and other cities.

FAUNISTIC DIVISIONS OF THE RIVER BELOW THE FALLS.

For our present purpose we may divide the river below the falls into four sections, fairly well separated by natural conditions, and by differences in the relative numbers of the various mussels. These sections will be discussed in order, beginning at the falls and proceeding toward the mouth of the river.

First section, from Cumberland Falls to Celina, Tenn., 175 miles.—While there are numerous and rich mussel beds along this portion of the river, there is no commercial clamming. This is chiefly due to the high percentage of culls, small species, and pinks, the latter mostly elephant-ear (*Unio crassidens*). The most important commercial mussel is the southern mucket (*Lampsilis ligamentina gibba*).

The elephant-ear is not killed in any great numbers by pearlers because it is not looked upon as a pearl-bearing species, while other mussels, supposed to contain pearls, are often nearly exterminated. Up to the present time, moreover, this mussel has been refused by the buyers for button factories. Consequently it has been neglected or culled out by the fishermen in the lower sections of the river and left comparatively free to breed, the glochidia to be picked up by fish and carried up toward the falls. Natural conditions have in some way also given the purple spike (*Unio gibbosus*) an advantage over other species above the falls. Similar conditions may have been equally favorable to the closely related elephant-ear below the falls. Perhaps these considerations will help to explain their preponderance in these two localities.

There are 19 mussel beds in this section of the river and the proportion of commercial shells and culls, together with the size of the bed and the kind of bottom, are shown in the following table:

First Section, Cumberland Falls to Celina, Tenn.

Mussel beds.	Percentage of commercial shells.						Percentage of culls.			Conditions.			
	Muckets.	Pigtoes.	Niggerheads.	Sand-shells.	Pocketbooks.	Warty-backs.	Spikes.	Elephant-ears.	Small or thin shells.	Size of bed.	Kind of bottom.	Temperature of air.	Temperature of water.
												° *F.*	° *F.*
Just below falls	24	....	....	1	6	10	15	7	25	Large	Rocks	81	84
Big South Fork opposite Parkers Lake	5	....	....	4	3	10	26	15	37	...do	...do	92	86
Big South Fork above Burnside	7	....	....	3	....	10	29	5	40	Medium	Gravel	86	82
Railroad bridge, Burnside	30	....	....	....	....	2	16	28	20	Small	...do	....	....
Fishing Creek Bar	35	....	....	5	....	....	16	28	10	...do	...do	86	85
Fords Island	....	....	....	....	....	....	20	60	20	Large	Sand	86	85
Mill Springs Bar	5	2	....	1	9	32	1	14	40	Medium	Gravel	86	82
Robertsport, Ky	22	....	....	....	9	15	2	20	25	Large	...do	....	....
One mile below Lock 21	10	....	....	2	....	....	20	50	10	...do	Mud	86	85
Horseshoe Bottom	12	....	....	3	....	....	20	45	10	...do	Sand	....	....
Beaver Creek	4	....	....	....	5	10	6	....	70	...do	...do	80	81
Indian Creek Shoals	40	1	....	2	5	2	6	40	4	...do	Gravel	87	81
Snow Island	5	9	14	1	....	5	1	39	20	Small	...do	....	....
Wells Island	40	1	....	....	1	....	....	50	8	Medium	...do	....	....
Selfs Shoals	40	....	....	....	3	....	....	50	6	Large	...do	....	....
Greens Bar	30	2	2	2	6	8	2	40	8	Medium	Sand	....	....
Champs Shoals	35	1	1	....	....	....	1	60	....	...do	Gravel	....	....
Biggerstaff Bar	10	10	....	....	....	33	2	18	15	Large	...do	80	82
Celina, Tenn	10	10	2	....	6	6	4	20	30	...do	...do	....	....

The table shows at a glance that the proportion of culls is so large in nearly every one of the beds that they yield but a poor profit to the clammer.

The conditions, however, are everywhere favorable to mussel growth, as is evidenced by the number and variety of the shells. These mussel beds each contain a fair proportion of commercial shells, three of which, the southern mucket, the butterfly, and the Ohio River pigtoe, might well be propagated artificially. In this way the preponderance of culls could be greatly reduced in a few years, if not wholly overcome.

Although there is no clamming, there is considerable pearling in this section of the river and large piles of shells were found in a number of places where the pearlers had left them. This was especially true at Fords Island, Mill Springs Bar, below Lock 21, Wells Island, Selfs Shoals, and Champs Shoals. It will be noticed that in coming down the river the first pigtoes were found at Mill Springs Bar and the second lot at Indian Creek Shoals.

Second section, from Celina to Nashville, Tenn., 190 miles.—The mussel beds increase a little in number and considerably in size along this section of the river, and in consequence there is more commercial shelling. The percentage of pinks and spikes steadily decreases, especially that of the former, and there is a corresponding increase in the commercial species. The Ohio River pigtoe becomes the most common button shell; while the elephant-ear not only decreases in numbers, but partially changes its color, and with

white nacre it answers fairly well for button making. The conditions are even better suited for mussel propagation than in the preceding section.

The following table gives the percentages of the various mussel species and other useful data:

SECOND SECTION, CELINA TO NASHVILLE, TENN.

Mussel beds.	Percentage of commercial shells.						Percentage of culls.			Conditions.			
	Muckets.	Pigtoes.	Niggerheads.	Sand-shells.	Pocketbooks.	Warty-backs.	Spikes.	Pinks.	Small or thin shells.	Size of bed.	Kind of bottom.	Temperature of air.	Temperature of water.
												°F.	°F.
Larrys Shoals	25	30	15	....	5	5	2	17	....	Small	Gravel	....	....
Roses Bar	20	25	10	....	10	10	5	20	....	...do	...do	....	....
Gainesboro Landing	5	....	....	....	....	....	....	....	85	...do	...do	....	....
Simpsons Island	20	30	10	1	....	5	10	20	5	Large	Sand and mud.	....	....
Saltlick Island	6	20	15	....	3	20	....	17	10	Medium	Gravel	80	79
Phillips Branch	20	15	15	1	5	10	6	20	....	...do	...do	....	....
Goodalls Island	20	15	15	2	6	15	2	20	4	Large	...do	80	83
Johnsons Eddy	20	25	10	1	5	12	....	25	....	Small	...do	....	....
Beasleys Bar	10	5	5	....	....	5	....	70	....	Large	...do	....	....
Cotton Bar	10	40	10	2	10	4	6	20	....	...do	...do	....	....
Puryears Bar	3	37	10	2	....	18	2	4	10	...do	...do	....	82
Cairo Island	20	35	10	....	2	15	2	15	....	...do	...do	82	85
Coles Ferry	30	25	10	....	....	10	1	6	10	...do	...do	....	....
Lindsleys Island	20	15	10	1	8	12	5	12	10	...do	...do	91	85
Hills Island	20	40	10	2	5	10	5	5	....	...do	...do	84	85

In addition to the beds above enumerated, small and not very profitable ones were reported by local clammers at Bullards Gap, 8 miles below Simpsons Island; at Wartrace Creek Bar, 4 miles further down the river; at Pinks Bar, 2 miles below; at Lower Holliman Island, a mile below Phillips Branch; at the head of Sullivans Island, 5 miles lower; at the foot of the sand shoals near Haneys Landing; at Turkey Creek Shoals, just above Carthage; at Hunters Point, a mile below Lock No. 5; at the mouth of Spring Creek, 5 miles above Cairo; at the foot of Cunningham Island, 2 miles nearer Cairo; at Mauskers Island, just above Edgefield Junction; and at Priestly Shoals, 5 miles above Nashville.

At Gainesboro Landing the mussels were all obtained from Roaring River, a tributary of the Cumberland from the south (see p. 29).

At Cotton Bar 12 tons of shells were cribbed along the bank, of which 60 per cent were pigtoes; washboards, monkey-faces, and butterflies were also common. Simpsons Island was the highest point on the river where clammers were found actually at work.

Muskrats were making heavy inroads into the mussel beds at several places, notably at Puryears Bar, at Mauskers Island, and Hills Island. All the piles of shells left by these animals showed that they have a decided preference for pigtoes.

Third section, from Nashville to Dover, Tenn., 105 miles.—This portion of the river has been more thoroughly worked by the clammers than has any other. It contains the largest and most valuable mussel beds of the entire river, and the location of all the beds, together with their size and relative value, are well known. The proportion of merchantable shells, moreover, has increased until there is no longer any locality in this part of the river where the pinks and spikes preponderate. The Ohio River pigtoe still continues to be the most common and valuable commercial shell, but the niggerhead becomes a close second and from Clarksville to Dover outranks the pigtoe.

So much does the commercial clamming increase and so great is the influence of the ready local market for shells that pearling as a distinctive vocation practically disappears. Every clammer is on the watch for such pearls as may be found in the shells which he cleans for the market, but there is very little hunting for pearls with no other object in view. This increase in the commercial clamming is due almost entirely to the activity of the button-blank factory at Clarksville, near the center of this third portion of the river, which furnishes a convenient market for all the shells taken in the vicinity.

The proprietor of this factory, Mr. M. K. Clark, is much interested in everything that pertains to clamming, and with his assistance several thousand glochidia of the yellow sand-shell were taken from ripe female mussels and placed in tubs of water with small fish caught in adjacent ponds. After the young mussels had fastened themselves to the fish the latter were turned loose in the river. This was the first time that mussels had ever been artificially planted in the Cumberland. Mr. Clark also gave us most of the data for the following table of mussels beds:

THIRD SECTION, NASHVILLE TO DOVER, TENN.

Mussel beds.	Percentage of commercial shells.						Percentage of culls.			Conditions.			
	Muckets.	Pigtoes.	Niggerheads.	Sand-shells.	Pocketbooks.	Warty-backs.	Spikes.	Pinks.	Small or thin shells.	Size of bed.	Kind of bottom.	Temperature of air.	Temperature of water.
												°F.	°F.
Penitentiary Bar	....	20	10	15	....	10	5	15	15	Large	Gravel	80	82
Robertsons Island	....	40	10	5	....	10	5	15	10	...do	...do	....	....
Gowers Island	2	50	5	5	2	5	....	25	5	Very large.	...do	....	....
Harpeth Island	5	45	5	5	2	10	5	15	5	...do	Mud	....	....
Half Pone Bar	5	10	15	....	5	20	1	2	30	...do	Gravel	81	78
Burtons Creek	5	10	10	5	2	15	5	10	15	Medium	Rocks	....	....
Cotton Gin Bar	5	15	10	5	5	10	5	30	10	...do	...do	....	....
Seven Mile Ferry	3	24	20	7	5	15	14	5	5	Large	Mud	....	....
Guisers Bar	3	55	10	5	1	15	1	8	....	...do	Gravel	....	....
Clarksville	5	30	20	10	5	10	5	10	....	...do	...do	....	....
Trices Landing	....	53	28	....	....	8	4	7	....	...do	...do	86	82
Meeks Spring	....	74	7	10	....	8	....	1	....	...do	...do	....	....
Martins Shoals	....	38	15	8	....	15	....	2	10	...do	...do	....	....
Hematite Bed	5	20	35	5	....	15	3	5	....	Small	...do	....	....
Carbondale Bed	....	25	20	8	5	20	2	1	10	Large	...do	....	....
Yellow Creek Towhead	5	30	20	10	5	15	....	5	5	...do	...do	....	....
Sailors Rest	....	30	25	10	....	15	....	4	7	...do	...do	....	....
Wild Cat Creek	....	25	20	6	....	12	....	5	10	...do	...do	....	....

There are also small beds containing a limited number of marketable species at the following localities: Just below Lock No. 1, along the north bank of the river, badly depopulated by sand dredges; near the Tennessee Central Railroad bridge, also along the north bank; at Whites Creek Bar, considerably dug up by sand dredging; along the mouth of Indian Creek, 20 miles below Nashville; below Lock A on the south bank of the river; at Betsytown on a very rough and rocky bottom; at Davis Riffle extending diagonally across the river; opposite the pumping station of the Clarksville waterworks; at Kentucky Landing and Red Rock Landing, the latter bed nearly worked out; at Palmyra Island along the west bank of the river; at Cumberland City just below the steamboat landing; and at Wells Island, 2 miles farther down the river.

Thus the third section of the river contains a larger number of mussel beds than any of the other sections, and the beds are richer both in numbers and species of mussels. It is the section of the pigtoe and niggerhead mussels, and those species are the most abundant button shells. There has also been a marked increase in the yellow sand-shell and the monkey-face.

This portion of the river, however, is also the nearest to the center of demand, and consequently its beds have been worked longer and harder than any of the others. The most of them do not show any signs of depletion but remain as rich as when the work first began. The most important beds are, for the conchologist, the one at Half Pone Bar, where the smaller and rarer species are specially abundant, and for the button man the one at Guisers Bar, which has yielded rich returns through a long series of years; in fact, from the very beginning of work here on the river.

Fourth section, Dover to Smithland, Ky., 85 miles.—While this section is not as well known as the preceding, and has not been worked as much, it probably contains as many and as valuable mussels.

The center of demand was still the blank factory at Clarksville, to which all the shells have to be transported up the river. But a sort of secondary center has been established at Dover, Tenn., where Mr. Walter, one of the leading merchants of the town, purchased most of the local shells and hired most of the clammers. Furthermore, the business in this part of the river was conducted in the most approved and up-to-date manner. The boats were towed to and from the mussel beds by small launches, the mussels themselves were conveyed from the boats up the steep river bank by steam power, and were finally cleaned by steam conveyed to the pans in a pipe from the engine.

Fourth Section, Dover to the Ohio River.

Mussel beds.	Percentage of commercial shells.						Percentage of culls.			Conditions.			
	Muckets.	Pigtoes.	Niggerheads.	Sand-shells.	Washboards.	Warty-backs.	Spikes.	Pinks.	Small or thin shells.	Size of bed.	Kind of bottom.	Temperature of air.	Temperature of water.
												° *F.*	° *F.*
Elk Creek Shoals	....	77	11	....	1	3	....	4	3	Large	Gravel	....	....
Walters Camp	5	10	25	10	5	15	....	6	5	...do	...do	....	....
Ball Island	....	70	9	....	8	2	3	3	5	...do	...do	....	....
Glasgow Landing	....	66	12	....	....	6	....	14	....	...do	...do	....	....
Dover Island	....	70	14	....	8	4	....	....	....	...do	...do	95	79
Jones Landing	....	70	6	8	6	5	1	2	....	...do	...do	84	78
Linton, Ky	....	76	10	6	....	5	....	2	....	...do	...do	85	75
Donelsons Landing	....	56	15	4	8	7	2	4	....	...do	...do	92	76
Canton, Ky	4	54	25	5	5	5	....	2	....	...do	...do	84	74
Eddyville Bar	....	26	26	....	34	6	....	6	....	...do	Rocks	86	73
Kuttawa, Ky	2	21	45	....	17	4	....	4	5	...do	Gravel	....	....
Money Cliff	....	9	51	....	37	....	....	2	....	...do	...do	....	....
Mussel Shoals	....	20	62	....	6	5	....	3	3	...do	...do	....	....

Mussel Shoals was the lowest point visited on the river, but from reports given by the clammers the niggerhead continues to be the prominent shell down to the mouth of the river.

The number of beds in this section of the river is fully equal to that of the preceding section, but they have not been worked as much because they are farther away from the center of demand and require transportation up the river to Clarksville. The niggerhead gains steadily in its percentage and at Canton passes the pigtoe, and then continues to increase down to the mouth of the river. There is also a steady decrease in the amount of culls, until at and below Canton nearly all the shells obtained were marketable. Of course, this means much to the clammer, as it does away with the necessity of sorting the shells and handling over the culls.

TABULAR STATEMENT OF DISTRIBUTION OF SPECIES.

In the table herewith given is expressed the distribution of every species of mussels obtained by the party in the Cumberland River and its tributaries. Where the mere presence of a species is all that is desired, it is indicated by an X. The percentages of the more important commercial species are indicated by numbers. The totals represent the actual number of specimens obtained. In order to catch the eye readily, all the side stations not on the main river are printed in italics. All commercial species are marked with an asterisk (*).

Distribution of Mussel Species in Cumberland River and Tributaries.

	Species.	*Clear Fork, Jellico, Tenn.*	*Clear Fork, Savoy, Ky.*	Cumberland, Pineville, Ky.	Cumberland, Barbourville, Ky.	Cumberland, Williamsburg, Ky.	*Laurel Creek, Corbin, Ky.*	*Rock Castle River, Livingston, Ky.*	Cumberland, above falls.	Cumberland, below falls.	*Big South Fork, Parkers L. Station.*	*Big South Fork, above Burnside.*	Main River, Burnside.	Cumberland, Fishing Creek.	Fords Island.	Mill Springs Bar.	Below Eadsville.	*Beaver Creek.*	Indian Creek Shoals.	Snows Island.	Tear-coat Bar.	Selfs Bar.	Champs Shoals.
1	Truncilla triquetra (snuffbox)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
2	brevidens	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....	X	....	....	....	....	....
3	arcæformis	....	....	....	....	....	....	....	....	....	....	XX	....	....	....	....	....	....	....	....	....	....	....
4	sulcata (cat's claw)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	haysiana (acorn)	....	....	....	....	....	....	....	....	....	2	XX	....	....	....	X	....	....	....	....	....	....	....
6	capsæformis	....	....	....	....	....	....	....	....	....	6	X	....	....	....	1	....	....	XX	....	....	....	....
7	florentina	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	X	....	....	....	....
8	walkeri, sp. nov	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
*9	Lampsilis ventricosa (pocketbook)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	ovata (pocketbook)	....	....	X	....	X	....	3	X	6	3	XX	....	....	....	9	9	XX	5	....	1	3	....
11	multiradiata	....	....	....	....	....	....	2	....	2	4	X	4	....	....	....	X	X	X	....	....	X	....
*12	ligamentina gibba (southern mucket)	....	....	....	....	....	....	....	....	24	5	7	30	X	....	5	22	X	40	5	40	40	35
*13	orbiculata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	1	....	....	....	....
14	tæniata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	picta	....	....	....	....	....	....	1	....	....	....	X	....	....	....	....	....	....	....	....	....	....	....
16	punctata	....	....	....	....	....	....	1	....	....	X	X	2	....	....	....	....	X	....	....	....	....	....
17	perdix	....	....	....	....	....	....	4	....	9	....	6	2	....	10	....	2	X	....	....	....	....	....
*18	anodontoides (yellow sand-shell)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
*19	fallaciosa (slough sand-shell)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
*20	recta (black sand-shell)	....	....	....	....	....	....	1	....	1	4	3	....	....	....	1	....	....	2	1	....	X	....
21	lienosa	....	....	....	....	....	....	....	....	X	....	....	....	....	....	....	....	....	....	....	....	....	....
22	vanuxemensis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
23	trabalis	....	....	....	....	....	....	....	....	5	2	....	2	....	....	2	....	....	....	....	....	....	....
24	parva	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
25	glans	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
26	alata (pancake)	....	....	....	....	....	....	....	....	1	X	X	....	....	....	4	2	X	1	....	....	X	....
27	gracilis (paper-shell)	....	....	....	....	....	....	....	....	....	X	....	....	....	....	X	....	....	....	....	....	....	....
28	lævissima (paper-shell)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
29	leptodon	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.	....	....	....	....	....
30	Medionidus conradicus	....	....	....	....	....	....	31	....	X	1	....	....	....	....	....	....	....	....	....	....	....	....
31	Obovaria retusa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
32	circula	....	....	....	....	....	....	.	....	....	2	....	....	....	....	14	....	X	....	....	....	....	....
*33	ellipsis (Missouri niggerhead)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14	....	....	....
*34	Plagiola securis (butterfly)	....	....	....	....	....	....	....	....	X	....	X	2	X	....	4	2	....	2	X	....	....	X
35	elegans (deer-toe)	....	....	....	....	....	....	....	....	2	....	X	....	....	....	2	....	....	....	1	....	....	....
36	donaciformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	X	....	....	....	....	....

37	Cyprogenia irrorata																2					×		
*38	Obliquaria reflexa (three-horned warty-back)								1		×				9	2		×	1					
39	Ptychobranchus phaseolus (kidney-shell)						1		10	1	2	2		10	1	4				1				
40	subtentus						4		×	12	2							×						
41	Dromus dromas											4	×		1	7		1	6	4	2			
42	caperatus (fan mussel)									5	×													
43	Strophitus edentulus schæfferiana	1					3	1		×	×	2							1					
44	Anodonta imbecillis																							
45	grandis (floater)																							
46	Lastena lata										×													
47	Anodontoides ferussacianus	1		×			3																	
48	Pegias fabula							2																
49	Symphynota costata (fluted shell)						3	8		5	1	×						×	×					
50	complanata (heelsplitter)																							
51	Alasmidonta minor	27	1	×	×		28		×															
52	truncata (elktoe)							2				×	2			2								
53	Margaritana monodonta (spectacle-case)													20					13					
54	Unio gibbosus (spike)	71	99	×	×	×	63	33	×	15	26	29	16		1	2	×	×	1					×
55	crassidens ("pink," elephant ear)									7	15	5	28	×	60	14	20		40	39	50	50	60	
56	Pleurobema clava (club-shell)							1			1	×												
57	crudum										×	×												
58	æsopus (bullhead)															2						×		
*59	Quadrula tritogonia (buck-horn)							2		4		×			1	7	×		1	×		×		
*60	perplicata (round-lake)							1							1	2	×					×	×	
*61	undulata (three-ridge)																							
*62	heros (washboard)														1									
63	cylindrica (rabbit's-foot)							1			×	×			1		×							
*64	metanevra (monkey-face)														1		×	×	4				×	
65	tuberosa																					×		
66	fragosa																							
*67	pustulosa (warty-back)									6	×				7	2		×	1					
*68	cooperiana (Cumberland pigtoe)														1				×	1				
69	rubiginosa (Wabash pigtoe)																							
*70	undata (pigtoe)																							
*71	obliqua (Ohio River pigtoe)										?				×	2	×	×	9				×	
72	coccinea							2			9	6	4		×		×	×		×				
*73	solida														4	2		×		×	×			
74	plena												×		×	×		×		×	×			
75	pyramidata										×				4	×				×	×			
*76	subrotunda									1	×													
*77	ebena (niggerhead)														×									
78	tuberculata (pink warty-back)								×	×	×				5		×	×			×			
79	granifera (pink warty-back)														2									
	Total number specimens obtained	70	200	×	3	10	35	458	×	810	389	275	50	×	100	77	45	×	×	76	×	×	×	

Distribution of Mussel Species in Cumberland River and Tributaries—Continued.

	Species.	Biggerstaff Bar.	Butlers Landing.	*Roaring River.*	Salt Lick Island.	Goodall Island.	Beasleys Shoals.	Cedar Bluffs.	Puryear Bar.	Lindsleys Island.	End Lindsleys Bar.	Hills Island.	*East Fork Stones River.*	*West Fork Stones River.*	Foot Gowers Island.	*Harpeth River.*	Half Pone Bar.	Seven-mile Ferry.	Owl Hollow Bar.	Guisers Bar.	Clarksville.	*West Fork Red River.*	Red Rock Bar.
1	Truncilla triquetra (snuff-box)	....	....	....	×	22	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	brevidens	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3	arcæformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4	sulcata (cat's claw)	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....
5	haysiana (acorn)	....	....	....	2	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....
6	capsæformis	....	....	....	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
7	florentina	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....
8	walkeri, sp. nov	....	....	....	....	....	....	....	....	....	....	....	70	....	....	....	....	....	....	....	....	....	....
*9	Lampsilis ventricosa (pocketbook)	....	....	....	....	....	....	....	....	....	....	....	1	....	....	×	....	....	....	....	×	....	....
10	ovata (pocketbook)	....	×	....	3	×	....	×	....	×	....	×	....	....	××	....	×	×	....	×	....	....	....
11	multiradiata	....	....	18	....	....	....	....	....	....	....	....	2	2	×	×	....	....	....	....	....	×	....
*12	ligamentina gibba (southern mucket)	10	×	....	6	×	×	×	2	×	....	×	....	....	×	....	×	3	×	×	....	....	×
*13	orbiculata	....	×	....	3	×	×	....	....	×	....	×	....	....	×	....	....	×	....	....	....	....	....
14	tæniata	....	....	....	....	....	....	....	....	....	....	....	....	26	....	....	....	....	....	....	....	....	....
15	picta	....	....	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16	punctata	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
17	perdix	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
*18	anodontoides (yellow sand-shell)	....	....	....	....	....	....	....	....	....	....	×	×	....	×	×	1	7	....	1	×	....	1
*19	fallaciosa (slough sand-shell)	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	1	....	....	....	....	....	....
*20	recta (black sand-shell)	....	×	....	....	....	×	×	....	....	....	....	....	....	×	×	×	....	....	×	....	....	....
21	lienosa	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	×	....	....
22	vanuxemensis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....
23	trabalis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
24	parva	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....
25	glans	....	....	10	....	....	....	....	....	....	....	....	×	2	....	....	....	....	....	....	....	×	....
26	alata (pancake)	2	×	....	3	×	×	×	....	....	....	×	....	....	×	....	×	×	....	1	×	....	×
27	gracilis (paper-shell)	....	....	....	1	×	....	....	1	×	....	×	....	....	×	....	1	....	×	×	×	....	×
28	lævissima (paper-shell)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....
29	leptodon	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
30	Medionidus conradicus	....	....	53	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....
31	Obovaria retusa	2	....	....	1	×	×	....	....	....	....	×	....	....	....	....	×	....	....	×	....	....	....
32	circula	2	....	....	4	....	....	....	....	....	....	....	2	....	....	....	×	....	....	....	....	....	....
*33	ellipsis (Missouri niggerhead)	2	....	....	....	....	....	×	1	×	×	....	×	....	×	....	3	7	×	2	×	....	1
*34	Plagiola securis (butterfly)	33	×	....	6	×	×	×	4	1	×	×	....	....	×	....	8	10	×	3	....	....	3
35	elegans (deer-toe)	....	....	....	....	....	....	....	1	×	....	....	....	....	×	....	6	....	×	....	×	....	....
36	donaciformis	....	....	....	1	....	....	....	....	×	....	....	....	....	×	×	33	....	×	....	×	....	....

37	Cyprogenia irrorata					×				×								×	×	×			
*38	Obliquaria reflexa (three-horned warty-back)				14	×	×	×		×	×	×			×		10	×	×	2	×		1
39	Ptychobranchus phaseolus (kidney-shell)	6				×	×	×			×				×		×						
40	subtentus																						
41	Dromus dromas		×			×	×	×	1	×					×			×					×
42	caperatus (fan mussel)																						
43	Strophitus endentulus schæfferiana					×		×									×						
44	Anodonta imbecillis												×	2									
45	grandis (floater)												1	26									
46	Lastena lata	2															×						
47	Anodontoides ferussacianus			1																			
48	Pegias fabula																						
49	Symphynota costata (fluted shell)	2	×	1				×					8	27	×	×					×		
50	complanata (heelsplitter)															×							1
51	Alasmidonta minor																						
52	truncata (elktoe)					×																	
53	Margaritana monodonta (spectacle-case)										×				×		×						
54	Unio gibbosus (spike)	2	×		1	×	×	×	1	×		×			×	×	1	14	2	1			3
55	crassidens ("pink," elephant ear)	18	×		17	×	×	×	3	×		×			25		2	×	8	8			5
56	Pleurobema clava (club-shell)																						
57	crudum																						
58	æsopus (bullhead)	×			1		×			×		×					×	×		×			
*59	Quadrula tritogonia (buck-horn)	2				×		×		×		×			×	×	1		×	1			×
*60	perplicata (round-lake)	×	×		1		×	×		×	×	×			×		3	21		1			5
*61	undulata (three-ridge)												5	15	×								
*62	heros (washboard)		×		1	×		×		×	25	×			×		2	24	×	8			
63	cylindrica (rabbit's-foot)					×				×							6	×			×		4
*64	metanevra (monkey-face)	3	×		3	×	×	×	6	1	×	×			×		2	3	7	4	×		
65	tuberosa																						
66	fragosa									×					×	×	2	3	1		×		1
*67	pustulosa (warty-back)	10	×		1	×		×	2	1	×	×			×	×	7	×	×	1	×		1
*68	cooperiana (Cumberland pigtoe)	2	×		1	×	×	×	2	×	×	×							1	1	×		1
69	rubiginosa (Wabash pigtoe)												5										
*70	undata (pigtoe)															×							
*71	obliqua (Ohio River pigtoe)	×	×		3	×	70	×	35	95	50	80			50		6	×	59	50			65
72	coccinea?																						
*73	solida		×		2					×								×	×				
74	plena							×							×		×	×					
75	pyramidata							×		×		×											
*76	subrotunda	×						×	1	×					×		×	×					×
*77	ebena (niggerhead)						×	×	1	×	×	×			×		1	7	8	8			6
78	tuberculata (pink warty-back)		×			×	×	×	4	×	×				×			×	3	3			
79	granifera (pink warty-back)																×						
	Total number specimens obtained	61	×	96	100	×	×	×	65	1,680	×	×	194	146	×	×	908	29	163	271	×	×	286

DISTRIBUTION OF MUSSEL SPECIES IN CUMBERLAND RIVER AND TRIBUTARIES—Continued.

	Species.	Trices Landing.	Above Meeks Bar.	Meeks Spring Bar.	Haynes Lake.	Elk Creek Shoals.	Walters Camp.	Above Ball Island.	Below Ball Island.	Glasgow Landing.	Head Dover Island.	Foot Dover Island.	Jones Landing.	Linton, Ky.	Mouth Donelson Creek.	Below Canton, Ky.	Eddyville Bar.	Above Kuttawa, Ky.	Below Money Cliff.	Horse Ford, below Kuttawa.	Penitentiary Bar.	*Red River, Port Royal.*	*Caney Fork.*
1	Truncilla triquetra (snuff-box)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	brevidens	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×
3	arcæformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4	sulcata (cat's claw)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	haysiana (acorn)	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
6	capsæformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×
7	florentina	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
8	walkeri, sp. nov	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
*9	Lampsilis ventricosa (pocketbook)	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	ovata (pocketbook)	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	....	×	3	....	....	×	×
11	multiradiata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
*12	ligamentina gibba (southern mucket)	....	....	....	....	....	×	....	....	....	....	....	....	×	....	1	....	....	....	....	....	×	×
*13	orbiculata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
14	tæniata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	picta	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16	punctata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
17	perdix	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....
*18	anodontoides (yellow sand-shell)	....	8	....	....	....	×	....	....	....	....	....	....	....	....	....	1	....	....	....	....	×	×	....
*19	fallaciosa (slough sand-shell)	....	1	....	....	....	....	....	....	....	....	×	8	....	....	×	....	1	....	1	×	×	....
*20	recta (black sand-shell)	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	1	1	....	×	×	....	....
21	lienosa	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
22	vanuxemensis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
23	trabalis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
24	parva	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
25	glans	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
26	alata (pancake)	....	2	....	....	....	×	....	....	×	2	×	×	×	....	....	....	1	....	×	....	×	....
27	gracilis (paper-shell)	....	1	×	....	....	....	....	....	....	....	×	....	....	....	....	....	×	....	×	....	....	....
28	lævissima (paper-shell)	....	....	×	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
29	leptodon	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
30	Medionidus conradicus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
31	Obovaria retusa	....	....	....	....	....	....	1	....	....	....	1	....	....	....	×	....	....	....	×	....	....	....
32	circula	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	×	....
*33	ellipsis (Missouri niggerhead)	....	5	×	....	....	....	1	3	....	....	1	1	....	2	1	....	×	....	....	×	....	....
*34	Plagiola securis (butterfly)	....	3	....	....	2	....	1	....	×	6	....	....	×	2	4	....	×	....	×	....	....	....
35	elegans (deer-toe)	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
36	donaciformis	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

37	Cyprogenia irrorata																								
*38	Obliquaria reflexa (three-horned warty-back)		19			1		3		×	6	3	1	1		1				×	×				
39	Ptychobranchus phaseolus (kidney shell)																					×			
40	subtentus																								
41	Dromus dromas																								
42	caperatus (fan mussel)																								
43	Strophitus edentulus schæfferiana								3													×			
44	Anodonta imbecillis				8																				
45	grandis (floater)				92																				
46	Lastena lata																								
47	Anodontoides ferussacianus																								
48	Pegias fabula																								
49	Symphynota costata (fluted shell)																					×			
50	complanata (heelsplitter)																					×			
51	Alasmidonta minor																								
52	truncata (elk-toe)																					×			
53	Margaritana monodonta (spectacle-case)						×																		
54	Unio gibbosus (spike)	4					×		3			1	×	1	2						×	×			
55	crassidens ("pink," elephant ear)	7	1	4		4	×		3	14		4	1	1	4	2	4	6		3	×	×			
56	Pleurobema clava (club-shell)																								
57	crudum																								
58	æsopus (bullhead)					1			3	×	2														
*59	Quadrula tritogonia (buck-horn)		4				×	3	3				×					×				×			
*60	perplicata (round-lake)		1			1		6		×	2		2			2	1	×		×	×	×			
*61	undulata (three-ridge)																								
*62	heros (washboard)	4	1	4		2	×	8			8	3	7	4	4	×	34	17	37	5	×	×			
63	cylindrica (rabbit's-foot)		3	×																					
*64	metanevra (monkey-face)		4	4		2	×	3	7	2		10	1	×	4	6	1	2		1	×				
65	tuberosa																								
66	fragosa	4	38	×								4	×	×		1	4	1	9	×					
*67	pustulosa (warty-back)		4			1	×	3		2		6	2	1	4	1	1	1			×				
*68	cooperiana (Cumberland pigtoe)			2			×	3	3					×	2	2				×					
69	rubiginosa (Wabash pigtoe)																								
*70	undata (pigtoe)		1			1								×			1	1							
*71	obliqua (Ohio River pigtoe)	53	1	74		77		60	72	67	70	58	70	76	56	49	26	20		20	×				
72	coccinea?																								
*73	solida																								
74	plena																								
75	pyramidata																								
*76	subrotunda																								
*77	ebenus (niggerhead)	28	2	7		6	×			12	2	12	6	10	13	23	26	45	51	62					
78	tuberculata (pink warty-back)						×	6		2					7	2					×	×			
79	granifera (pink warty-back)																								
	Total number specimens obtained	28	156	×	27	93	×	69	38	56	51	73	365	328	45	79	143	269	35	181	×	×			

RELATIVE ABUNDANCE OF DIFFERENT SPECIES.

In forming an estimate of the relative abundance of the different mussels in the various beds many things have to be taken into consideration.

For the clammer's purpose, a count of his entire catch would give the most reliable data, but this is usually impossible. It is almost as satisfactory to take the successive hauls as they come and count the various species in each; the greater the number of hauls counted the more accurate the results obtained.

From the viewpoint of the conchologist, however, such an estimate is in reality only a measure of the extent to which the species in question is capturable by the clammer's gear, and for the following reasons:

There are a number of species which never "bite" the hooks on a crowfoot dredge, or which do so very rarely. Such species may be plentiful in a mussel bed and yet never appear in the clammer's hauls.

Again, some mussels are found only in small numbers and around the edges of a bed. The clammer makes his hauls where the shells are most crowded, through the center of the bed, and may miss these altogether.

The clammer throws away the mussels that are too small to use as well as those whose shells are too thin or too highly colored. Such shells ought to enter into the percentages as much as the more valuable species, but they do not appear in the clammer's hauls.

Different methods of clamming produce very different results in the proportion of shells obtained. The crowfoot dredge, the rake, the tongs, and wading each secure an unduly large number of some species and an unduly small number of other species.

To enumerate all the shells obtained by all the methods would give the most accurate results, but that is obviously impracticable. When the water is low the clammer gets quite a different proportion of species, and may even get different kinds of mussels from those obtained when the water is high.

Each of these considerations has been kept in mind while making out the percentages; the clammer's hauls were counted; all the piles of culls were carefully examined; all the specimens possible were secured by wading along the edges of the beds; account was taken of the various shells found in muskrat piles; the relative stage of water was noted, and, so far as could be done, allowance was made for it. Then, too, there has been a careful consideration of numerous circumstances which can not be shown to the reader, but which result from the authors' experiences at the different stations. Notwithstanding all these efforts, the numbers must still be regarded as

approximate rather than absolute. But, even so, they will be of service to the mussel fishermen, for whom they are primarily intended. Only a very small percentage of the shells seen and handled could be kept for the final collection.

An endeavor was made to retain typical specimens of each species encountered, and also all puzzling and aberrant forms, since the latter add much to the actual knowledge of a species, though they may render positive identification more difficult.

SUMMARY OF MUSSEL DISTRIBUTION.

The practice of the Bureau of Fisheries in examining a river and its tributaries from source to mouth, in regular order, throws unexpected light on the distribution of species which could be obtained in no other way. The fauna of a river has a coherence never found and not to be expected in an artificial division of the country, such as a township, county, or State, whose boundaries are purely arbitrary. The larger the river and the more thoroughly the main stream and its tributaries are examined the more illuminating become the results. The study of the entire fauna of the Cumberland River and its tributaries leads to the following general conclusions, which are amply confirmed in all the river faunas that have been examined:

1. When two closely related forms differ essentially in their degree of inflation, the flatter and less inflated one will be found in the upper portions of the river and in the tributaries, while the rounder and more inflated one is confined to the lower portions of the main river, where there is a weaker current and more mud. To this there are, however, some noteworthy exceptions, such as *Symphynota complanata*.

2. The swiftness of the current, the size of the stream, and the kind of bottom affect other shell characters besides that of inflation. Consequently, where there is a mixture of conditions there is also a mixture of characters, and two species which in other localities may be well defined and easily separated will be found to merge imperceptibly into each other. In a miscellaneous collection of shells it is easy to find the blue-point (*Quadrula undulata*) from one stream and the three-ridge (*Q. plicata*) from another, the southern mucket (*Lampsilis ligamentina gibba*) from one locality in a State and the pocketbook (*L. ventricosa*) from another. But when specimens of the entire fauna of a river are spread out on a table in order from the source to the mouth there is found such a mingling of characters that it is often a mere matter of individual judgment to determine some of the species. This is essentially true of *Q. undulata* and *Q. perplicata* in the upper portions of the Cumberland.

3. There is sometimes a peculiar similarity in the faunas of widely separated tributaries, where the conditions at first would seem to be

very different. Such a similarity is found in Roaring and Rock Castle Rivers, although the localities are widely separated and the surrounding country quite different.

4. Some species demand peculiar conditions, and their presence or abundance in any locality depends on the presence and extent of the favorable conditions.

The washboard (*Q. heros*) lives in holes or depressions in the bottom, full of soft mud. Any mussel bed in the Cumberland that has such holes will be likely to contain washboards, whether that bed is high up the river or low down toward the mouth, and the percentage of the washboards will depend on the area covered with such holes.

5. The Cumberland is very different from the Maumee and Kankakee Rivers in that it shows a marked differentiation between small and large stream species, between the main river and its tributaries, but there is very little evidence of migration along the main river itself.

Such species as are confined to the upper, middle, or lower portions of the river owe their habitat chiefly to the fact that here, as elsewhere, they frequent smaller or larger streams, as the case may be.

Accordingly, we may distinguish the following classes:

(*a*) Small-stream species restricted to the upper portions of the river and its tributaries. Here belong seven species. *Anodontoides ferussacianus* was found only in the tributaries and not at all in the main river. The other six species, *Lampsilis perdix, multiradiata, orbiculata*, and *punctata*, and *Alasmidonta minor* and *truncata* are distributed in various tributaries and in the main river both above and below the falls. None of these are commercial species.

(*b*) Large-stream species, restricted to the lower portions of the main river. There are nine of these species, seven of which are not found in any of the tributaries, viz: *Lampsilis ventricosa* and *fallaciosa, Obovaria retusa* and *ellipsis*, and *Quadrula heros, ebena*, and *fragosa*. The other two species, *Lampsilis anodontoides* and *Quadrula undata*, were found in Harpeth River and the former also in Red River as well as in the main Cumberland. The most of these large-stream species are good button shells, as would be expected. Indeed, the only exception is *Obovaria retusa*, which is the smallest of them all and for that reason the least valuable.

(*c*) Species of universal distribution, which are well scattered throughout the entire length of the main river. There are seven of these species, three of which, the Ohio River pigtoe (*Quadrula obliqua*), the pink warty-back (*Q. tuberculata*), and the butterfly (*Plagiola securis*), are not found in any tributary. The other four are the southern mucket (*Lampsilis ligamentina gibba*), the pocketbook (*L. ovata*), the spike (*Unio gibbosus*), and the elephant-ear

(*U. crassidens*). The last two, of course, are culls, but all the others are valuable commercial shells.

(*d*) Species confined to restricted areas, including all of the rare forms that are of interest chiefly to the conchologist. These include all of the Truncillas, which were found in places widely separated from one another, and one of which was new to science; nine species of *Lampsilis—tæniata, picta, lienosa, vanuxemensis, trabalis, parva, glans, lævissima,* and *leptodon*—all of which are too small or too thin-shelled to be of any value. *Dromus caperatus* and *Symphynota complanata;* two *Anodontas, imbecillis* and *grandis;* two Pleurobemas, *clava* and *crudum;* and four Quadrulas, *undulata, tuberosa, rubiginosa,* and *granifera.* These last four have some commercial value but not very much.

6. The great bulk of the mussel fauna of the river is thus made up of the seven universally distributed species, and two of the large stream mussels—*Quadrula heros* and *Q. ebena.* All the others are confined to such restricted areas or occur in such small numbers as to possess only an incidental or accessory value.

NOTES ON THE VARIOUS STATIONS.

THE UPPER RIVER AND ITS TRIBUTARIES.

This portion of the river was examined by Mr. Boepple in 1910 as well as by the present party in 1911. Both the river and its tributaries are rather swift mountain streams which are much used as a source of power to run small gristmills, and hence they are frequently interrupted by dams. The bottom is mostly bedrock sandstone, with occasional fissures and sand and gravel pockets and bars, the latter furnishing the only localities where mussels can live. Consequently the shells are very few in number and widely scattered. The Clear Fork has more sand bars and pockets than the main river, and hence considerably more mussels.

Mr. Boepple in his notes called attention to the apparent presence of acids in the water above the great falls, which quickly dissolved the nacre of dead shells, and the present party observed the same thing. Moreover, in the small beds above the falls the muskrats had made considerable inroads into the mussel fauna. Against so many unfavorable conditions the mussels find it very hard to hold their own, and the few species able to survive are not of any importance either to the pearlers or the button manufacturers. These mussels above the falls are not only thin-shelled but are much dwarfed, and *Unio gibbosus*, the most common species, has a very pale nacre, which frequently becomes white or yellowish and approaches closely a dwarfed form found in Green River, Ky.

THE RIVER BELOW THE FALLS AND ITS TRIBUTARIES.

Not only were there a great number of additional species below the falls, but there was also a change in the character of the shells. This was especially noticeable in *Unio gibbosus*, which was no longer a pale-nacred dwarf, but was of normal size and color. The mussels are usually found crowded about the base of the large rocks along the bottom of the river just below the falls. They are easily accessible to their enemies, especially during low water, and many of them are killed by muskrats, raccoons, mink, and occasional otter. But the relative number lost in this way is very small when compared with the corresponding loss above the falls. Hinge pearls (baroques) are common in this portion of the river, especially in the pocketbook (*Lampsilis ovata*), nearly every specimen of which contains a few. The river from Anvil Shoals, 1 mile below the falls, to Burnside was not investigated either by Mr. Boepple in 1910 or by the present party in 1911, but it was reported by a mussel fisherman to be full of excellent button shells. The bottom is much too stony for any kind of gear, however, and it would be necessary to collect the mussels entirely by hand. Pearling has been conducted actively along this portion of the river, and piles of shells left by the pearlers were frequent along the shore. Indeed it was reported that pearling had practically cleaned out the river for the first 10 miles above Burnside. There are two tributaries, both from the north, which enter the Cumberland in this space between the falls and Burnside.

Rock Castle River is the larger of the two and is nearer Burnside. It was examined below the ford at Livingston, Ky., July 1. The shores here were high and rocky and were forested with a mixture of deciduous trees and hemlock. The water was clear, temperature 81°, with a maximum depth of a foot and a half. The current was slow (2 miles per hour) and the bottom was very rocky and rough, with only a few bars and patches between the rocks filled with clay. The flora was remarkable and wholly unlike any that we saw elsewhere. Nuphar grew along the water's edge, *Myriophyllum verticillatum*, a broad-leaved *Potomogeton*, and a small patch of *Scirpus americanus* grew in the shallow water, and there was plenty of water willow, the whole reminding one of a bit of creek in northern Indiana or Illinois. The mussels were excessively abundant in the sand and clay patches here, and in favored localities the little *Medionidus conradicus* covered the entire bottom with the elongate slits, which is all of the mussel that can be seen.

Nineteen kinds of mussels were found here, but only a very few of them possessed commercial value, and a few miles farther down the river all the species were widely scattered. This shell bed was markedly unlike any of those in the main river, containing some

species that were not found in the Cumberland at all, and others that were quite rare. In these respects they resemble those found in Roaring River in Tennessee.

Laurel Creek, a tributary of Laurel River, was examined below the dam at Corbin, Ky., July 3. The shores were rocky and were heavily wooded with a deciduous forest, mixed with hemlock and pine, and still supported a remarkably rich and varied flora. The dam cuts off the upper portion of the river, and no mussels were found above it. There was a city dumping ground near at hand and the water was milky in color and covered with a greasy scum. Below the dam the bottom was very irregular and mostly solid rock, full of potholes and patches of sand and destitute of vegetation.

We had expected to find a rich and varied fauna, something like that of the Rock Castle River, but could discover only five species, and three of these were represented by a single shell each. This river thus has almost identically the same species as the Clear Fork and the Cumberland above the falls. The poverty of species is doubtless due to the smallness of the stream and the general unsuitable conditions.

There was no dwarfing of the species, but there were several peculiar modifications in the color of the nacre which were not found in the main river. These suggest that while there is some intercourse with the Cumberland there is very little interbreeding.

The Big South Fork flows into the Cumberland at Burnside, Ky. Our party examined it first opposite Parkers Lake, where there is a fish trap and a low dam. The shores there were high limestone cliffs, the water was very clear, and the bottom was coarse gravel covered with bowlders and great angular fragments of rock, with some sand between them. Dead shells, recently killed by muskrats, were abundant on the rocks and on the dam at the fish trap. Twenty-eight species were obtained here, but although seven or eight of them were good button shells, they were not sufficiently abundant to make the gathering of them profitable. At Sloans Shoals, 6 miles from Burnside, during the autumn of 1910, Mr. Boepple found about 20 species, securing them all with a rake. At the riffles, 2 miles above Burnside, the present party found large but rather scattered beds of mussels, by far the greater number of which were noncommercial. There were 32 species in all, and evidently some of them had yielded good returns in pearls, for there were many piles of shells along the river bank and the bed had been thoroughly worked over.

Minute marginal cysts were abundant in the edge of the mantle of *Unio gibbosus*, often leaving small pits along the margin of the shell. Baroques and the distomid of Kelly were found in *Quadrula tuberculata*, and a few large *Atax* in *Symphynota costata*. Several of the *U. gibbosus* and two of the *Pleurobema* were gravid. The latter

had fine red eggs in all four gills and the body was orange; the former had coarse white glochidia in only one pair of gills.

On proceeding down the main river from Burnside the first mussel bed of note is on the bar below the mouth of Fishing Creek. Very few living mussels were seen here, but the entire river bed was covered with shells which had been killed by pearlers. A large number of beautifully marked univalves were present among the dead mussel shells.

At Fords Island the bottom of the left chute, which we examined most carefully, is a shingly gravel, in which it was difficult to find the mussels. Mr. Boepple, who examined this bed in 1910 with a mussel rake, reported an "almost unbelievable quantity" of *Unio crassidens*. The present party would probably have obtained many more mussels if the bed could have been examined during low water.

Four miles farther downstream, at Mill Springs, is another long and straggling mussel bed, which covers several miles of the river bottom. The latter is here composed of shingly gravel, with some sand bars, and is largely covered with water-willows.

The pearlers' piles along the banks opposite this bed were chiefly the shells of *Unio crassidens* (elephant-ear) with some *Dromus* and *Quadrula obliqua* (Ohio River pigtoe). Although this was not an important shell bed it was noteworthy for the increase in the number of species. The pocketbooks (*L. ovata*) found here were the first typical ones seen.

At the pearling camp 1½ miles below Eadsville or Lock 21 we found the water about 2 feet above normal and rising rapidly, with a swift current over a gravel bottom. The pearlers were farmers from near by, who carried on pearling at odd times. They had thrown their opened shells back into the river, and there were about a ton and a half of them lying in the shallow water along shore. The pocketbooks (*L. ovata*), muckets, and elephant-ears were the most numerous species. Mr. Boepple investigated Gands Island, in this vicinity, and found the mussels, especially *Unio crassidens*, abundant on both sides of the island, an unusual circumstance.

Beaver Creek is a small tributary of the Cumberland from the south, opposite Rowena, Ky. This creek was investigated for a mile, up to a series of long riffles. The bottom was rocky with considerable mud and sand, in which were obtained a surprising variety of shells for so small a stream, as is shown in the table.

In the mouth of Goose Creek, a little way down the river, a man was seen actively pearling with a fork. He said that he was getting mostly elephant-ears and that there were plenty of muckets on the other side of the river but the water was too high to work them. Mr. Boepple saw a fine lot of about 50 pearls in Rowena during his stop there in 1910.

Indian Creek Shoals, 53 miles below Burnside, is one of the most interesting mussel beds of the upper river. We found the water clear with a swift current over a gravelly bottom. Near the water's edge was a pile of about 300 pounds of shells left by a pearler. These were mostly pocketbooks and muckets, but contained a good sprinkling of sand-shells, *Dromus*, and monkey-faces. Mr. Boepple obtained a good collection of shells from this bed in 1910 and also from Copper Island a little farther down the river.

Snows Island is a large island covered with coarse pebbles, upon which many dead shells had drifted, while others along the shore had been freshly killed by muskrats. At the head of Weeds Island, a little way below, there was about a ton and a half of shells left by pearlers, chiefly the southern mucket and elephant-ear.

At Tear-coat Bar on July 20 the water was muddy and high from a heavy rain the night before. The bottom here is black gravel mixed with yellow sand. Out of a ton and a half of shells left here by pearlers about 90 per cent were southern muckets and elephant-ears and the remaining 10 per cent an admixture of other species.

Selfs Bar contained a large and populous mussel bed which had been the center of active pearling operations. The 3 tons of shells left by them contained about the same percentage of shells as at Tear-coat Bar.

Marrowbone Creek, a small tributary from the north, was examined up to the first riffles, a mile or more, but contained no mussels. In general the northern tributaries of the Cumberland were rather barren, while those from the south were well populated. On the top of a hill near the mouth of this creek was an old shell pile left by the Indians, and from this point these shells became quite frequent, especially near the sites of old camping grounds.

At Champs Shoals pearling was being actively carried on, and there was a large pile of discarded shells, two-thirds of which were elephant-ears, while nearly all of the other third were southern muckets. The river here widens out considerably, and there is more clay and sand on the bottom. The shell bed continues with some interruptions from this bar down to Burkesville. At Tobins Landing, below Burkesville, Mr. Boepple obtained a fine collection of shells, representing at least 14 species.

At Cloyds Island, below Tobins, there is an unusually good mussel bed which has been much worked by pearlers. The banks along both sides were fairly covered with the shells left by them, principally southern muckets and elephant-ears. In this bed the mussels were thickest where the current was strongest.

Biggerstaff Bar and Island were examined July 24; at the head of the island were a few shells among which were found specimens of *Lastena lata*, a rare species.

A few rods below the bar there were several good-sized shell piles left by muskrats, from which we obtained an exceptionally fine lot of butterfly-shells (*P. securis*). From Martinsburg to Celina there were a few pearlers' piles which increased in size and number of shells as we approached the latter place.

The Obey River, a tributary from the south which enters the Cumberland at Celina, Tenn., and the Cumberland itself in the vicinity of Celina, were examined by Mr. Boepple in 1910 and again in 1911. He covered the lower 26 miles of the Obey River, beginning at Grass Lot Shoals, where no mussels were found. At Martins Bar a large collection was obtained representing 22 species, of which the southern mucket and the pocketbook were the most abundant. The bottom here was firm coarse gravel. At Holmes Bar 24 species were secured, the southern mucket being still the most abundant. The current was swift and the coarse gravel bottom was covered with a rich vegetation, in which the mussels were especially abundant. The southern mucket is the only shell in this river worthy of commercial consideration, the others being too scarce. Mr. Boepple estimated that when niggerheads are worth $30 per ton these muckets would be worth $50.

From 12 to 15 years ago there was considerable pearl fishing on the Obey River, and a local firm said that then one could easily get a wagonload of mussels a day. But now the larger mussels are gone and the small ones have only small pearls. Fourteen of these pearls which were examined weighed from 2 to 4 grains each, but were of extra quality.

In the Cumberland, 1 mile below Celina, there is a fair-sized mussel bed which has been worked for 10 years, entirely for pearls. The most valuable commercial species is still the southern mucket, and this is also regarded as the best pearl bearer.

Mr. Boepple examined a large bed near Butlers Landing and secured 13 species, but the specimens were all too badly eroded and spotted to have any commercial value. A storekeeper here had a number of pearls which he had taken in trade, and he showed us an assortment of 4 purple, 5 yellow, and 8 white ones, of the rosebud type, all of which had an exceptionally good luster.

About 3 miles below Butlers Landing we found the first pile of commercial shells we had seen, but they were all old shells, since no active clamming had been carried on for two years. There were 6 or 7 tons in the pile, most of them of second quality, the Ohio River pigtoe being the most common, with the southern mucket and the Cumberland pigtoe (*Q. cooperiana*) close seconds. There were fully 2 tons of culls, 98 per cent of which were elephant-ears and the purple warty-back. Mr. Boepple secured a fine collection of shells from this bed with the crowfoot dredge, and among them were 3 specimens of

Lampsilis fallaciosa, the slough sand-shell, which were the first obtained during our survey of the river.

At Brimstone Island there is a large mussel bed in water from 2 to 8 feet deep, with a bottom of coarse gravel, sand, and clay. Commercial clamming had been in operation here only a few days before our arrival, but must have been carried on during previous years, as evidenced by a pile of button shells on the bank containing fully 20 tons.

At Carsons Bar there is another large mussel bed in water from 3 to 6 feet deep, with a moderate current and a hard gravel bottom. This bed is worked only occasionally by local fishermen chiefly for fish bait and pearls.

Roaring River, a tributary from the south which enters the Cumberland just above Gainesboro Landing, was examined several miles above its mouth on July 28. Only one small mussel bed was found along the shore under the shade of the overhanging trees, in 3 to 6 inches of water on a gravelly bottom. The presence of a large amount of *Potomogeton* and the abundance of *Medionidus conradicus* was a strong reminder of the Rock Castle River at Livingston, Ky. The abundance of *Lampsilis glans* was also noteworthy, since this species was not found anywhere in the main river.

At Gainesboro Bar there is a small mussel bed which can not be worked with a crowfoot dredge, since the bottom is composed of flat rocks with gravel pockets in the cracks. At the lower end of the bed, where the rocks were well covered with a blue clay, the mussels were of especially fine quality, but the bed has never been fished commercially.

We reached Salt Lick Island when the water was low and the mussels were moving about actively. Similar conditions were found at Half Pone Bar (see p. 33), and the extremely interesting collections obtained at each of these stations show what a remarkable difference a low stage of water makes in the results of collecting. There is no reason for supposing these two beds to be exceptionally good, and probably most of the beds in the Cumberland would have nearly if not quite equaled them if the conditions under which they were examined had been equally favorable. This Salt Lick Island bed was especially noteworthy for the large numbers of *Truncilla* that were obtained. No parasites were found on any of the mussels. *Lampsilis gracilis* was gravid (July 31), while *L. ligamentina gibba* and *L. orbiculata* approached each other so closely in all their shell characters as to be indistinguishable except by the color of the nacre and epidermis.

At Fort Blount Bar there is a large mussel bed in water from 4 to 6 feet deep, with a swift current over a bottom of firm gravel mixed with yellow clay and sand. Two men from the Ohio River had been

working here for a week before our visit, and two more began on the day of our arrival. The Ohio River pigtoe is the most common button shell.

At Granville our party was caught in a very heavy rain, almost a cloudburst, and went from there down to Carthage on high and turbid water which rendered any satisfactory mussel survey impossible.

Sullivans Island was investigated by Mr. Boepple when the conditions were more favorable. He found a large mussel bed in a strong current on a bottom of rough gravel and yellow clay. Although he secured 22 species, and among them a large number of Ohio River pigtoes and southern muckets, the bed is worked only for fish bait and pearls. Two small beds at Buffalo Bar and Sand Shoals are not of commercial value.

Caney Fork, one of the most important tributaries of the Cumberland, joins the latter river just above Carthage. In Buffalo Valley, near Flat Pond, July 27, Mr. Boepple found a mussel bed covering the entire width of the fork and 1½ miles long. He used a crowfoot dredge and scissors fork in water 5 to 10 feet deep on a bottom of coarse gravel mixed with sand and yellow clay. This bed has been fished for pearls and baroques during the last 15 years, and according to accounts it has yielded well. None of the shells have ever been sold, and fully a carload of merchantable species was seen scattered along the banks.

At Rock Springs there is a much smaller bed in a swift current, with water 2½ to 8 feet deep, the bottom being flat rocks on one side and much fine sand and gravel on the other. This bed has also been fished for 15 years for pearls and baroques, and while the shells are exceptionally good for button purposes they have never been utilized. The spectacle-case (*M. monodonta*) was once common here, but has been nearly exterminated by being used for fish bait. Another bed at Lancaster Island shows similar conditions; the button shells are of first quality, but have never been utilized.

At the lower end of Goodall Island in the main river below Carthage there are two small beds separated by a short interval. The current is slow but steady, while the bottom is of firm gravel mixed with yellow clay. There was a pile of about half a ton of shells here. Down nearer to Lock 7 there is a third bed in water from 14 to 16 feet deep, which was fished for pearls up to 1908, two years before the lock was finished. The Ohio River pigtoe is the principal commercial species here, with a good sprinkling of second-grade button shells. The effect on this bed of the dam at the lock seemed to be to kill off the mussels at the lower end, but to allow the upper end to broaden out considerably. The clammer here opened all his shells with a knife instead of steaming them, since he was working principally for pearls.

He was reported to have found three during the preceding week, one of which sold for $100.

At Beasleys Shoals there is a large and important shell bed with several good-sized piles of shells along the banks. These piles aggregated about 10 tons, and the Ohio River pigtoe furnished 80 per cent of the merchantable shells in them. They represented chiefly the residue of a great amount of clamming done here in the past. An Ohio River clammer had taken out 200 tons of good shells and left about 8 tons of culls, of which the elephant-ear formed 90 per cent. The bottom was gravel mixed with yellow clay and covered with 12 to 16 feet of water. Of 5 pigtoes examined 4 were gravid, 2 had young in the outer gills only, while the other 2 had a number of young in the inner gills also. The *Quadrula subrotunda* had orange flesh while part of the gills contained carmine eggs, most of which had been aborted.

Below Cedar Bluffs we found a pile of 12 tons of shells which had been collected a year or more before, and cribbed. The mussel bed here was large with a very slow current over a bottom of gravel covered in some places with clay. The bed has been extensively fished for pearls; during the previous year (1910) 8 boats had been employed and they collected over 100 tons of shells, more than half of which were saved and sold. But there was fully a carload of good button shells scattered along the banks.

Goose Creek, a tributary of the Cumberland from the north, was examined August 10, but although the conditions seemed in every way favorable no mussels could be found.

At Daniels Landing the mussel bed is half a mile long and 150 feet wide in water 12 to 16 feet deep, with a bottom of yellow clay and sand changing to rocks at the lower end. The fishing here has been chiefly commercial since pearls are scarce. Eight men fished this bed in the summer of 1910 and obtained 100 tons of shells, the principal commercial mussel being the Ohio River pigtoe, which is of extra-large size and of the best quality. A few very large niggerheads were also found. In spite of the large amount of shells taken from this bed it still remains one of the richest in the river.

At the mouth of Spring Creek, below Hunters Point, there is a large mussel bed 1 mile long and 125 feet wide, in a very slow current over a bottom of gravel and yellow clay covered in places with mud. This was first fished in 1910, when 50 tons were taken; at the time of our visit in 1911 the clammers had obtained about 14 tons, nearly all of Ohio River pigtoe, with a few washboards and niggerheads. Another large mussel bed was reported at the foot of Wings Eddy Bar, and still another at Armstrongs Island. At Cairo we saw a pile of 12 tons of shells, mostly Ohio River pigtoes.

At Grallatin Landing the mussel bed is 1½ miles long and from 40 to 60 feet wide, on a bottom of gravel and yellow clay covered with mud. The river widens considerably, there is much dead water, and the shores are low, making the conditions almost lake-like. This is all the result of excessive backwater from the lock dam just below. The first *Quadrula fragosa* was found here.

At the head of Lindsleys Island we found a very large number of small shells killed by muskrats; 95 per cent of these shells were pigtoes. There is no commercial fishing here nor even any pearling. We found in this bed our first yellow sand-shell, and also a spectacle-case, specimens of which we had not seen for some time. Farther down the river, at the end of Lindsleys Bar, there was a clammer's camp. About 600 pounds of shells had been collected, of which the pigtoe formed 50 per cent, the washboard 25 per cent, and the remainder mixed species, including a few yellow sand-shells. There was a good mussel bed at Hills Island above Nashville on a muddy bottom in a fairly rapid current. Many mussels had been killed by muskrats who seemed to have a particular liking for small pigtoes.

Stones River, an important tributary from the South, was examined along its East Fork at Walterhill, Tenn. The water was shallow and turbid with numerous riffles; the bottom was composed of loose rocks with intervening gravel bars, covered with plenty of water willow.

Below the ford was found a large number (70) of a beautiful new species of *Truncilla* (see p. 46), many individuals of which had been killed by muskrats. The *Symphynota costata* found here were remarkably large, and contained many lusterless pearls.

The West Fork of this river was visited at Murfreesboro, Tenn. It is somewhat larger than the East Fork and is broken up by divers islands covered with water willows. There were many *Anodonta grandis* and *Symphynota costata* of large size on the bank, recently killed by pearlers.

The mussel fauna here is remarkable in containing several species not found at all in the Cumberland, and in a peculiar interchange of species. *L. ovata* of the Cumberland is replaced here by the genuine *L. ventricosa* and *Q. perplicata* is replaced by *Q. undulata*. The presence of *Q. rubiginosa* is unexpected, and that of the genus *Anodonta* is interesting, since this is the only place in the Cumberland or its tributaries where representatives of this genus were found.

At the foot of Gowers Island, 25 miles below Nashville on the main river, there is one of the most important mussel beds in the entire Cumberland. And we found here the largest pile of mussel shells yet seen, about 80 tons with 8 tons of culls. The bed is 3 miles long and from 60 to 175 feet wide in a strong current on a bottom of gravel mixed with sand and clay. The young pigtoes here were all so

brightly rayed that for a time they were regarded by the clammers as possibly a new species. Harpeth River, a tributary from the south which enters the Cumberland a little way above Lock A, was examined 5 miles above its mouth. The bottom here was of shingly gravel, changing to solid rock and farther up to beds of soft mud. There was formerly a large mussel bed here, but the backwater from the lock dam has killed the mussels in the lower portion of the bed. Another large bed was reported $1\frac{1}{2}$ miles farther up the river.

The unusual size and thickness of the shells obtained here suggest that this river would yield exceptionally good button material. The margins of the shells were much pitted, indicating parasites in unusual abundance. The presence of fine large *L. ventricosa* and *S. costata* so near the mouth of the river is remarkable, since both of these species are absent from the Cumberland.

Below Lock A we saw numerous sites of old shell piles where clamming operations had been carried on in the past. At Half Pone Bar the current was swift, the water shallow and somewhat turbid, and the bottom firm gravel and sand. The large number of specimens and species is at least partly due to the peculiar configuration of the bottom and the low stage of the water, the conditions being similar to those at Salt Lick Island (see p. 29). The great majority of the shells obtained were young, but many of them were eroded at the umbones. *P. donaciformis* was exceptional in being very thin and having a pink nacre. The large number of *Plagiola* is noteworthy, together with the only specimen of *Truncilla florentina* found below Nashville.

At the Seven Mile Ferry above Clarksville the current was rather feeble, the water clear, and from 5 to 8 feet deep, and the bottom composed of fine gravel. From this point on down the river a crowfoot bar was employed, similar to that used by commercial clammers but shorter and smaller, and furnished with 50 hooks. The latter were of two kinds, the ordinary form used by clammers and an improved form invented by Mr. Boepple, having a knob at the tips to prevent small mussels from taking hold or larger ones from dropping off. Hauls were made 200 feet long, the first as near the shore as possible, and each succeeding one 10 feet farther out. The detailed record of the different hauls made at a few stations is given in full, in order to convey a more accurate idea of the number and distribution of the mussels, and the ease or difficulty with which they could be caught. Such a record was kept for all the stations in this portion of the river, and forms an important factor in determining the relative abundance of the mussels.

At Owl Hollow Bar, $2\frac{1}{2}$ miles above Clarksville, we found a swift current with clear water over a clay bottom, more or less mixed with gravel. This bed had been worked for eight years and showed signs

of depletion. The detailed record of the 14 hauls made here is given in the following table:

HAULS MADE AT OWL HOLLOW BAR.

Number of haul	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total.
Duration in minutes	4	4	4	3	3	5	4	3	3	6	4	9	4	6	
Lampsilis ligamentina gibba	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
Obovaria reflexa	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1
ellipsis	....	....	....	....	....	....	1	....	....	....	....	....	....	....	1
Plagiola securis	....	....	....	....	....	....	....	....	....	1	1	....	....	....	2
Unio crassidens	1	3	....	1	....	3	1	1	....	....	....	1	1	....	12
gibbosus	....	....	....	....	....	1	....	....	1	....	....	1	1	....	4
Quadrula heros	2	....	1	....	....	1	....	2	....	....	....	....	....	....	6
obliqua	13	9	14	6	4	7	4	....	2	3	3	16	5	4	90
ebena	2	1	1	1	....	....	3	1	....	2	1	3	1	1	17
tuberculata	....	....	1	....	....	1	....	....	....	....	....	....	1	1	4
cooperiana	....	....	....	....	....	1	....	....	1	....	....	....	....	....	2
fragosa	....	....	....	....	....	....	1	....	....	....	....	....	....	....	1
metanevra	....	....	....	....	....	....	....	1	2	5	5	1	1	1	16
pustulosa	....	....	....	....	....	....	....	....	....	1	1	....	....	....	2
Total	18	13	17	8	4	14	10	6	7	12	11	22	10	7	159

This was one of the most important mussel beds visited, since clamming was going on actively at the time of our visit, the shells being used at the Clarksville blank factory. The bed has been worked for 10 years with from three to six boats every summer, but it shows very little sign of depletion. In sorting the shells the washboard (*Q. heros*) is piled by itself, because it is badly stained, and sold at one-half or one-third the regular price. It forms about one-fifth of the entire catch.

Of the first-grade shells the pigtoes are much the most abundant, followed by the niggerhead and the monkey-face. Mussel enemies are scarce, most of the mink and muskrats having been trapped. Pearls and baroques are rare, slugs run about three-quarters of an ounce to the ton. A large number of the pigtoes obtained were gravid and several had young in all four of the gills.

At Clarksville June 12 the river was very low and a large sand bar was being uncovered. The bottom was fine gravel and the water rather shallow, with a slow current. The yellow sand-shells were traveling rapidly into deeper water. *Plagiola donaciformis* was gravid.

At Red Rock Bar, below Clarksville, on June 6 the water was unusually clear, about 8 feet deep, and there was practically no current, the bottom firm gravel. Fourteen hauls were made here under the same conditions as at Owl Hollow Bar, save that each was 300 feet long. The mussels found gravid here were 1 *O. reflexa*, 2 *U. gibbosus*, 3 *Q. perplicata*, 1 *Q. pustulosa*, 77 *Q. obliqua*, and 10 *Q. ebena*. This is the only place in the main Cumberland that we found *S. complanata*. This bed has been worked eight years and begins to show the effects of it. The shells obtained are of better quality than when the work first began, but there are fewer slugs,

the shells being younger. *Quadrula perplicata*, called locally the "round-lake," is the pearl bearer here.

HAULS MADE AT RED ROCK BAR.

Number of haul	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total.
Duration in minutes	7	6	2	6	8	2	9	12	5	9	12	14	11	4	
Lampsilis ligamentina gibba	....	....	....	....	....	....	....	....	....	....	....	1	....	....	1
anodontoides	....	1	....	....	....	....	1	....	1	....	....	....	....	....	3
gracilis	....	1	....	....	....	....	....	....	....	....	....	....	....	....	1
alata	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1
Obovaria ellipsis	....	....	....	....	....	....	....	1	1	....	1	....	....	....	3
reflexa	....	....	....	....	....	....	1	....	2	1	....	....	....	....	4
Plagiola securis	....	....	....	1	....	....	....	....	1	2	....	2	....	2	8
Unio crassidens	3	3	....	....	1	2	....	1	3	....	....	....	....	2	15
gibbosus	....	....	1	2	....	....	1	2	....	1	....	1	....	....	8
Symphynota complanata	1	1	....	....	....	....	....	....	....	....	....	....	....	....	2
Quadrula heros	3	1	....	....	....	....	2	....	2	1	....	1	2	....	12
obliqua	21	2	6	17	20	12	25	12	3	13	8	18	10	20	187
ebena	3	2	....	1	1	....	2	....	....	....	1	....	3	5	18
cooperiana	....	....	....	....	1	....	....	1	....	....	1	....	1	....	4
fragosa	1	....	....	1	....	....	....	....	....	....	....	....	....	....	2
pustulosa	3	....	....	....	....	....	....	....	....	....	....	....	....	....	3
perplicata	1	1	....	....	1	2	5	....	2	1	....	....	....	....	13
Total	36	12	7	22	24	16	37	18	15	19	11	23	16	29	285

Trices Landing is 1½ miles below Clarksville and the conditions are almost exactly the same as at Red Rock bar, except that the bed is full of "hang-ups," and therefore not fished commercially.

At Meeks Spring bar, about 8 miles below Clarksville, some fine springs enter the river, one of which has its outlet richly incrusted with diatomaceous scum. The current was very slow and the water unusually clear over a bottom of coarse gravel. This bed has been fished for 10 years and 500 or 600 tons of shells have been taken from it. Most of the *O. reflexa* and *Q. fragosa* were found cleaned at muskrat holes and were practically the only shells there. The yellow sand-shell and the rabbit's foot had been going shoreward during a previous rise in the river, but turned and went back when the water fell. Many of these sand-shells were gravid June 10 and were used in making a plant of mussels in the river at Clarksville.

The Red River is the only tributary of any size that enters the lower Cumberland from the north. No mussels could be found for several miles above its mouth, probably because the bottom was found to be covered with soft mud which shifted considerably during high water.

At Ringgold, on the west fork of the river, there is a high milldam, which backs the water up for several miles. No mussels were found above this dam, and below it they were rather scarce and all of small species. Several *L. multiradiata* were found which showed no rays, a few *L. vanuxemensis*, and one live *L. glans*. This proved to be the only place where *vanuxemensis* occurred.

Mr. Boepple visited Port Royal, at the junction of the two forks of Red River, on June 14. The river here is not large and is shallow

except a few deep holes; the bottom is gravel and mud. The mussels were collected with a rake and by wading, and were mostly near the bank in the mud, only a few being found in the gravel. Sixteen species were obtained in all, two of which, *S. costata* and *S. complanata*, were rare in the main river. The mussels were said to have been formerly abundant, but they had been nearly cleared out by pearlers, and not enough marketable species were left to make fishing profitable.

Haynes Lake lies several miles below Clarksville, on the north side of the river, and is apparently a part of the old river channel. It is about a mile long and surrounded by woods; the bottom is soft mud and the water is about 3 feet deep, with a temperature of 89°. Very large specimens of *Anodonta grandis gigantea* were obtained, 2 of which contained sporocysts of some distomid, while 2 others were gravid (Sept. 4). The nacre of 8 was purplish, that of the remaining 17 a beautiful creamy white. Of the 2 specimens of *A. imbecillis* 1 was gravid.

Elk Creek Shoals, 13 miles above Dover, had a current of 3 miles an hour in water 10 feet deep over a bottom of gravel mixed with some sand. Nine of the pigtoes obtained here were gravid (May 30), and on the land bar above the shoals was found one dead *Truncilla sulcata*, a species which is exceedingly rare in the Cumberland.

Walter's shelling camp was about a mile below these shoals, and Mr. Walter very kindly conveyed us up and down the river in his launch, giving much valuable information. He had a pile of shells containing about 150 tons, of which the most important button shells, in the order of their abundance, were the Ohio River pigtoe, the Cumberland pigtoe, the monkey-face, the yellow sand-shell, the butterfly, the niggerhead, and the southern mucket.

At Glasgow Landing, 2 miles above Dover, on May 29 the current was about 4 miles an hour, the water high and muddy but rapidly falling, and the bottom gravel mixed with clay. About one-third of the pigtoes were gravid, the glochidia being usually in the lower half of the outer gills. The niggerheads were also in the early stages of gravidity, all four gills being red and padlike; one elephant-ear was gravid. At the foot of Dover Island the conditions are the same as just recorded except that the water was 20 feet in depth. A small species of *Atax*, with broad white marks on the back, was found on several of the mussels obtained here. Marginal distomid cysts were fairly common, especially in *P. securis* (the butterfly). This same butterfly was frequently gravid, the pigtoe was less often gravid, and a single specimen of *Q. fragosa* had glochidia in all four gills.

A noteworthy feature of the lower river, somewhat marked at Clarksville, but decidedly more so at Dover and below, is the land-

slips that occur along the banks, when great masses of earth slide into the water, sometimes carrying trees with them.

At Jones Landing there was another clammers' camp, operated by a Mr. Scarborough, who rendered us considerable assistance. The water here was 15 feet deep and the current about 3 miles an hour over a bottom of mud and gravel. Sixteen hauls were made here, with the following results:

HAULS MADE AT JONES LANDING.

Number of hauls	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16[a]	Total.
Duration in minutes	15	8	6	5	4	2	2	4	8	6	6	8	5	8	4	4	
Lampsilis anodontoides	....	....	....	....	....	....	1	2	....	....	....	....	....	....	....	....	3
gracilis	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	1
alata	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1
Plagiola securis	1	1	1	....	1	....	....	....	....	....	....	....	1	2	....	....	7
Unio crassidens	....	1	....	....	2	....	....	....	....	....	....	1	1	....	....	....	5
gibbosus	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	1
Obovaria ellipsis	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
reflexa	....	....	....	....	1	....	....	....	1	1	....	....	....	....	....	....	3
Quadrula heros	2	2	5	1	2	....	....	3	1	3	....	6	....	1	....	....	26
obliqua	13	15	12	12	31	14	....	20	18	24	4	32	21	27	25	....	268
ebena	1	....	1	1	4	....	....	3	....	2	....	4	5	....	2	....	23
tuberculata	1	....	....	....	1	....	....	....	1	....	....	1	1	....	....	....	5
fragosa	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1
metanevra	....	....	....	....	....	1	....	....	....	....	....	....	....	1	2	....	4
pustulosa	1	1	....	....	1	....	....	....	2	....	....	1	....	....	2	....	8
perplicata	....	2	....	2	1	1	....	....	....	....	....	1	....	....	....	....	7
plena	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1
tritogonia	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1
Total	19	22	19	16	44	18	1	28	23	32	5	46	31	31	31	0	366

[a] No mussels taken.

At Three Sisters Springs, near Linton, Ky., some remarkably large springs flow out of a cave into the river. There was a current of 4 miles an hour in water 20 feet deep over a bottom of soft gravel. No parasites were found except distomid cysts along the margin of the mantle of a few shells. Stained and rough tips, which in some places indicate pearl formation, were common in the shells here. Six of the pigtoes had the lower half of the outer gills filled with glochidia (May 24). All the mussels examined had their intestines filled with greenish mud and appeared well fed.

The main bed is a little below the springs and had been worked for four seasons. Our helper, who had been a professional clammer, had on one occasion dug in this bed 13 boxes of shells of 100 pounds per box in one day. This was in competition with another man who dug 12 boxes in the same time—a ton and a quarter by the two men in a single day.

Below Linton shell beds are common but none were being worked above the mouth of Donelsons Creek. The largest of these beds is at Dead Mans Bar, where there was a large pile of culls near the mouth of Terrapin Creek.

At Donelsons Creek a clammer had just begun working and had only a few shells, chiefly pigtoes, washboards, niggerheads, and

monkey-faces. A mile below Canton, Ky., there is another bed in 12 to 15 feet of water which had been worked previously as was evidenced by an old shell pile, in which a single valve of *L. fallaciosa* was found. In the hauls here taken by our party were obtained, May 23, four gravid niggerheads and five pigtoes.

The bed at Eddyville, Ky., examined May 18, was on a gravel bottom covered with 15 feet of water, with a current of about 2 miles an hour. This bed had been worked more or less for four years, but was difficult and unsatisfactory on account of numerous "hang-ups."

Just above the Ferry at Kuttawa, Ky., there was a large mussel bed on a bottom of sand and gravel, covered with 8 or 10 feet of water, with a swift current. Eighteen hauls were made with the following results:

HAULS AT KUTTAWA, KY.

Number of hauls	1	2	3	4	5	6	7	8	9	10	11 *a*	12 *b*	13 *a*	14 *c*	15	16	17	18	Total.
Duration, minutes	3	3	6	4	4	4	4	3	4	6	5	2	4	5	5	2	5	5	
Length in feet	100	200	100	100	100	30	100	50	50	100	100	30	60	40	100	30	100	100	
Lampsilis fallaciosa	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
orbiculata	....	....	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	....	2
ovata	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1
recta	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	1
alata	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1
gracilis	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1
Quadrula heros	....	6	5	3	6	1	....	7	....	....	....	1	....	....	....	4	....	1	34
ebena	1	8	4	3	18	....	....	1	....	26	....	....	....	....	6	....	9	12	88
obliqua	....	2	....	7	11	....	8	3	....	2	....	....	....	....	....	....	7	8	48
fragosa	....	....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	1	1	4
metanevra	....	....	....	1	2	1	3	1	....	2	....	....	....	....	....	....	....	....	10
pustulosa	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	1	....	2
perplicata	....	....	....	....	....	1	....	....	4	....	....	....	....	....	....	....	8	....	13
trigona	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1
tritogonia	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	1
Unio crassidens	....	....	1	4	1	....	3	1	....	1	....	....	....	....	....	....	2	3	16
Plagiola securis	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Total	1	17	12	20	39	3	17	14	4	34	0	1	0	0	6	4	29	25	226

a No mussels, due to shifting sand. *b* Water 50 feet deep. *c* No mussels.

Of the gravid mussels obtained in these hauls the elephant-ear (*U. crassidens*) had the entire outer gills padlike, striate, and white. *Lampsilis orbiculata* has a marsupium that is black-edged, while the mantle is striated brown and black like that of *L. ventricosa*. The pigtoes (*Q. obliqua*) were just beginning to become gravid (May 13), with minute white spawn along the crenate edge of the outer gills. In *Lampsilis gracilis* the posterior half of the outer gills had much the appearance of a lima bean, in which the conglutinates were somewhat separated, with no black edge and no furrows.

CHARACTER OF WATER OF THE CUMBERLAND RIVER.

In the coal regions of the upper Cumberland River the water is generally clear and of an acid nature. The acidity is well shown by the limy parts of the dead shells being greatly dissolved away and in

many cases the epidermis alone left. That the mussels do not thrive well in this portion of the river is probably due to the fact that the bottom is rocky, food scanty, and the water deficient in lime.

Below the Cumberland Falls in the limestone formations the water contains a considerable percentage of lime. Here the shells are much larger and thicker than those above the falls.

The table given below is taken from the United States Geological Survey "Water-Supply Paper 236," by R. B. Dole, and shows the mineral conditions of the Cumberland River, at Nashville, Tenn., and Kuttawa, Ky., two widely separated localities of the lower river. A sample of water was taken daily, these mixed, and a sample from the mixture was taken for analysis. There were about 3 analyses made per month, or 36 per year. This method gives a much better general knowledge of the conditions than a single sample would do. From Nashville the samples were collected from October 24, 1906, to November 3, 1907, and 35 analyses made; from Kuttawa, from January 11, 1907, to January 11, 1908, 34 analyses were made.

The following table gives the general average of the analysis, in parts per million, and also the per cent of the anhydrous residue:

MINERAL ANALYSES OF WATER FROM CUMBERLAND RIVER.

[Parts per million, unless otherwise stated.]

	Near Nashville, Tenn.		Near Kuttawa, Ky.	
	Mean.	Anhydrous residue.	Mean.	Anhydrous residue.
		Per cent.		*Per cent.*
Turbidity	126	.....	176	.....
Suspended matter	94	.....	165	.....
Coefficient of fineness	.74	.....	.92	.....
Silica (SiO_2)	20	16.4	18	14.6
Iron (Fe) [a]	.42	1.5	.30	1.4
Calcium (Ca)	26	21.3	28	22.8
Magnesium (Mg)	3.6	2.9	4.3	3.5
Sodium and potassium (Na+K)	9.6	7.8	7.8	6.3
Carbonate radicle (CO_3)	0	37	.9	40.6
Bicarbonate radicle (HCO_3)	92	.....	100	.....
Sulphate radicle (SO_4)	14	11.4	9.7	7.9
Nitrate radicle (NO_3)	1.2	1.0	1.8	1.5
Chlorine (Cl)	2.1	1.7	3.0	2.4
Total dissolved solids	119	.....	124	.....

[a] Fe_2O_3.

COMMERCIAL VALUE OF THE MUSSELS.

Taking into consideration both the relative abundance of the species and the intrinsic value of the shell, the southern mucket (*L. ligamentina gibba*) is the most important commercial mussel of the upper river; that is, from Burnside down nearly to Nashville.

From Nashville to Clarksville the mucket is not relatively as abundant, and is consequently surpassed in value by the Ohio River pigtoe (*Q. obliqua*).

From Clarksville to the mouth of the river the honors are divided between the pigtoe and the niggerhead (*Q. ebena*). There are other shells all along the river which possess a high intrinsic value but are not found in sufficient quantities to equal the ones just mentioned. The most important of these are the yellow sand-shell (*L. anodontoides*), the most valuable of all our fresh-water species, the butterfly (*P. securis*), *Lampsilis orbiculata*, a shell of very high value and desirable for propagation, and the Missouri niggerhead (*O. ellipsis*). The Cumberland pigtoe (*Q. cooperiana*) and the long niggerhead (*Q. subrotunda*) are also much esteemed by the button manufacturers. Samples of shells from the upper portions of the river were carefully weighed, measured, and appraised by Mr. Boepple, with the results indicated in the following table:

COMMERCIAL VALUE OF MUSSEL SHELLS TAKEN FROM THE CUMBERLAND RIVER IN OCTOBER AND NOVEMBER, 1910.

Species.	Locality.	Weight.	Number shells.	Number blanks.	Lines.	Number gross per ton.	Value per gross.	Value per ton.
		Pounds.					*Cents.*	
Lampsilis ligamentina gibba.	Martinsburg, Ky	5	16	287	.....	685	5	$34.25
Do	Coes Landing, Ky	2½	12	180	20	916	6	54.96
Do	Martinsburg, Ky	5	17	222	20	522	3	15.66
Do	.....do	5	17	222	20	723	5	36.15
Do	Burnside to Burksville	5	32	390	.....	928	5	46.40
Do	Obey River, Celina, Tenn.	5	12	57	36	135	20	27.00
				129	20	307	7	21.49
Quadrula obliqua	Coes Landing, Ky	5	37	76	30	180	10	18.00
Dromus dromas	Martinsburg, Ky	2½	11½	23	35	109	15	16.35
Lampsilis ovata[a]	.....do	2½	11½	T 67	.....	319	2	6.38
Dromus dromas and small Quadrulas mixed.[b]	.....do	2	34	125	.....	744	2	14.88
Unio crassidens	.....do	2½	13½	137	20	652	.....	.....

[a] Tips. [b] Pearly tips.

A good idea of the extent of clamming operations on the river below Nashville may be obtained from the following data, contributed by various shell buyers at Paducah, Ky.: On some of the beds mussel fishing has been conducted for at least 10 years. One mussel firm, with headquarters at Paducah, had 300 boats operating from Paducah to Nashville. In 1907 this company obtained 1,783 tons of shells from this part of the Cumberland River; in 1908, 1,400 tons; in 1909, 1,100 tons; in 1910, 1,125 tons. In consequence of a sudden drop in the price of shells this company was not working the river during 1911.

Another buyer reported 500 tons obtained from the same region of the Cumberland by his company during each of the years 1907, 1908, and 1909, but only 100 tons in 1910.

In addition to these companies there were Ohio River parties and private fishermen operating in the river, which must have increased the annual output to considerably over 2,000 tons per year.

Because of the drop in prices mentioned above, none of the larger companies were operating the river during 1911 with the exception of Mr. Walter, at Dover, Tenn., and the blank factory at Clarksville, Tenn.

BREEDING SEASON OF THE CUMBERLAND MUSSELS.

Throughout the progress of the survey the various species of mussels were examined as to breeding condition and the date at which the various species were found gravid is shown in the table following. In addition to the table, which gives only the bare facts, the following additional notes will prove of interest and value.

The only *Lampsilis ovata* found gravid was on May 13. Mr. Boepple sent in some gravid examples during the late autumn of 1910. Without doubt this species is usually gravid from autumn until the next spring. *L. multiradiata* was found becoming gravid July 28. In other streams we have found it fully gravid in September and October. *Lampsilis anodontoides* was found fully ripe in abundance from June 10 to 21. The breeding season of this species is well known; it usually becomes gravid in autumn and remains so during the winter. *Quadrula perplicata* was noticed becoming gravid May 24, and gravid samples were still found July 27. Although *Quadrula cooperiana* remained gravid for a considerable length of time, we saw only a few samples; the citations refer to single individuals, so that, while we have it recorded from June 3 to August 11, only 11 gravid examples altogether were seen. The characteristics of the gravid mussel are described under the discussion of the species. It is a desirable species to propagate. *Quadrula obliqua* is the most prolific mussel in the river, and we saw many more gravid examples of this than of any other species. From June 3 to 10 is the height of its breeding season, and at that time about half the catch obtained would be gravid. When the life history of the species is known and the fish which serves as host, it will be easy to procure material for propagation during a considerable part of the summer.

Quadrula ebena was observed in early stages of gravidity about the beginning of the work, and gravid examples were obtained as late as July 16. The other species noted are not of special economic importance and gravid examples were found only in small numbers. Sufficient information about them can be obtained by a glance at the table.

TABLE OF GRAVID SPECIMENS OF MUSSELS FOUND IN THE CUMBERLAND, 1911.

Dates.	L. ovata.	L. multiradiata.	L. anodontoides.	L. vanuxemensis.	L. gracilis.	M. comradicus.	O. circulus.	O. ellipsis.	O. reflexa.	A. imbecillis.	A. grandis.	U. gibbosus.	U. crassidens.	P. clava.	Q. perplicata.	Q. cylindrica.	Q. metanevra.	Q. pustulosa.	Q. fragosa.	Q. cooperiana.	Q. obliqua.	Q. coccinea.	Q. subrotunda.	Q. ebena.	Q. tuberculata.
May 13	×				×								×								×				
15																					×			×	
17																			×						
18																	×								
23								×																×	
24									×							×					×			×	
29																			×		×				
June 3									×				×		×		×			×	×			×	×
5									×			×					×			×	×			×	
6																		×			×				
7																					×				
10			×																		×				
16									×																
17			×													×									
21				×																					
28														×											
29														×											
July 1						×								×		×	×								
8																				×	×				
9							×								×					×	×	×			
10															×						×				
11																				×	×			×	
13											×									×	×				
14																				×	×	×		×	
15																					×			×	
16																				×	×				
27															×	×					×			×	
28		×																							
31					×																				
Aug. 9																					×				
10																				×	×		×		
11																				×	×				
17																				×	×				
18																					×				
21																					×				
Sept. 2																									
3																									
4																									
9										×	×														

PEARLS AND PEARLING IN THE CUMBERLAND.

Just when pearling began on the Cumberland there is no definite record. It has been in operation quite steadily on the upper river for at least 20 years. It is not generally carried on actively the year round, but chiefly in August and September, when the water is low. There are few professional pearlers, however; that is, men who devote their entire time to the gathering of pearls. Most of the pearling is carried on by farmers at odd times, and by men who in the winter devote their energies to lumbering, chopping, or trapping.

Hunting for pearls is confined mostly to the upper river and the tributaries. It seems that the conditions suitable for pearl formation are more abundantly fulfilled in small streams.

The first sign of active pearling operations seen by the present survey was encountered about Burnside. The search for pearls extended above the town as far as Seven Mile Shoals and downstream as far as Celina, and less actively to Carthage and beyond. A short

distance below Burnside pearling has been recently in active operation, at Pittman and Fishing Creek. From Burnside down to Burkesville Mr. Boepple had noted in 1910 that the river bed was well filled with shells killed by pearlers, and in 1911 the same work was being continued farther on downstream. At Patty Shoals below Mill Springs in 1910 "yellow mussels" (*L. ligamentina gibba*) had been pretty well fished out, since the pearlers opened only this species.

In order that due allowance may be made for the inevitable degree of unfounded rumor on such subjects, we will give at first the reports of the rivermen and supplement them later by our own observations.

At Burnside we heard that a pearl had been found at the mouth of Pittman Creek which was worth $250 or $300 and another that had been sold for $40, and we were told of a man living down the river, back some distance in the country, who had a fad for pearling and buying pearls, and who had accumulated in this way about $20,000 worth of pearls, baroques, and slugs at the time our informant visited him. Many pearls had been found in the vicinity of Eadsville, the highest price any single pearl from that locality brought being $800.

In August and September 100 men were often pearling at once on a shoal near Rowena, and the highest price paid for any single pearl was $500. There had also been much pearling on a mussel bed below Tear-coat Bar and on another at Clouds Island during the past five years, sometimes as many as 50 men working at the same time. At Goodall Island, for 20 years previous to the time of closing the lock, pearling had been in active operation. At one time 150 men were at work together on the bed, and in one week $30,000 worth of pearls were found. Pearling had also been carried on near the mouth of Goose Creek above Hartsville in former years, but it stopped after the building of the lock below, which flooded the beds with lock water and rendered it difficult to obtain the mussels.

Not only the upper river but its tributaries also were famous for pearls. At Carthage it was said that better pearls were found in the Caney Fork than in the Cumberland, and that they commanded a much better price. Mr. Boepple, who investigated the lower 26 miles of the Obey River at Celina, remarks: "Twelve to fifteen years ago there was much pearl fishing here, and it seems to have paid until, indeed, the mussels had been fished out by pearlers." Stones River was in good repute as a pearling stream, and a merchant at Clarksville stated that his father used to buy many pearls from there. There had been active pearling on this river only a short time before our visit, and some shells left by the pearlers and examined by our party showed indications of pearl formation. Red River, which enters at Clarksville, is said to be a good pearl-bearing stream in its upper

portion, and we saw a number of very good pearls from there. Little River, across from Canton, Ky., is also said to yield numerous pearls, which, however, are rather small.

Our own observations, as well as the records of people engaged in the pearl trade, indicate that pearling was once an important occupation in the upper river. We saw in many places large piles of shells left by pearlers along the river banks, and came across one party actively engaged in pearling. Mr. Boepple saw a collection of pearls in Rowena valued at $1,000, and this represented only a portion of those found in the vicinity, since the largest and finest pearls were sent directly to New York. At Butlers Landing a storekeeper showed us a very pretty collection of "rosebud" pearls, all with a good luster, four of which were purple, five yellowish, and eight white.

At Clarksville, as mentioned above, we saw some very pretty pearls from Red River. One of the principal merchants at Carthage buys about $15,000 worth of pearls every year. The highest price he had paid for a single pearl was $2,500. They generally range from $20 to $300. A shell buyer at Paducah, Ky., bought $2,000 worth of pearls during the season of 1910. While genuine round pearls are not common in the lower river, rough pearls and baroques are usually present to the amount of three-fourths ounce per ton of shells. The baroques vary from $2.50 to $3.50 an ounce.

On account of the ground to be covered and the time at our disposal, together with unfavorable weather while on the upper Cumberland, we did not have opportunity to devote very much attention here to pearl formation, though this region would prove an exceptionally good location from which to attack the problem. In looking over the flesh of some mussels recently killed by pearlers a number of black distomid cysts, similar to those found in the Maumee River (Indiana and Ohio), were observed, and these probably figured in part at least as an exciting cause.

A study leading to the discovery and the consequent conservation of the peculiar conditions which favor pearl formation in the upper Cumberland and its tributaries, accompanied with active propagation of the southern mucket in that region, would be highly desirable. The mussels are not yet so nearly exterminated that gravid material can not be readily procured, though it is feared that they soon will be, in view of the active depredations of the pearlers. It is believed that mussel planting could be kept well ahead of any onslaught likely to occur and that the resulting harvest would yield not only an abundance of the very best button material but also a plentitude of pearls, and thus prove a source of much greater benefit than where mussels are reared for the shells alone.

DISCUSSION OF MUSSEL SPECIES.

In the list of species here presented we have followed in most respects the classification and sequence given in Simpson's well-known Synopsis of the Naiades. In the spelling of the names, however, we have followed the suggestions of Lindahl[a] and have made also a few minor changes, such as the substitution of the older name *Quadrula undata* for *Quadrula trigona*, as suggested by Mr. Bryant Walker, and the transference of the *Medionidus subtentus* (Say) to the genus *Ptychobranchus*, and of *Tritogonia tuberculata* (Barnes) to *Quadrula* under the name *Quadrula tritogonia*, as suggested by Dr. Ortmann. Many other changes have been proposed which will probably in the end prove justifiable. We have avoided making any shifts between *Pleurobema* and *Quadrula*, although several have been advocated which may be desirable. The fact that both *Pleurobema æsopus*, *Quadrula obliqua*, and another perplexing form which we have found may have glochidia in two, three, or all four gills indicates that these two genera should really be united.

We are very favorably inclined toward the new classification proposed by Ortmann,[b] but its present state of incompleteness and the uncertain position of many species, as well as our own conclusions regarding *Quadrula* and *Pleurobema*, make it seem best at present to use the older and better known system with the few exceptions noted above.

1. *Truncilla triquetra* Rafinesque. Snuffbox.

This attractive little shell occurs only in the upper part of the river. In all we procured 21 specimens, 19 of which were obtained at Salt Lick Bar. In the autumn of 1910 Mr. Boepple found it at Indian Creek, Cloyds Landing, Albany Landing, and in the Obey River at Celina, Tenn.

It is in all probability considerably more common and widely distributed in the river than our collections would indicate. But it does not seem to occur as far down the river as Half Pone Bar or at Clarksville; if it did a few examples would certainly have been taken among the great number of small mussels collected in that region in June.

Truncilla triquetra is a small species, dwelling in the shallower water. On account of its small size it is rarely or never taken on the mussel dredge or rake, but must be gathered by hand. It has a handsome, strong and thick shell, but is too small to have any commercial value. All our examples are pretty well eroded at the umbones.

2. *Truncilla brevidens* (Lea).

This species was not found in the main river at all and only at three stations altogether. It was most abundant in the Big South Fork opposite Parkers Lake Station. Three examples were procured in the same fork 2 miles above Burnside and one in Beaver Creek. It is too small to have any commercial value.

All the specimens found were dead, but some had been recently killed by muskrats, therefore nothing was learned concerning its habits. It appears to be a species

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[a] Lindahl, J.: Orthography of names of the Naiades, The Journal of the Cincinnati Society of Natural History, vol. XX, no. 5, art. VIII.

[b] A monograph of the Najades of Pennsylvania, reprinted from the Memoirs of the Carnegie Museum, vol. 14, no. 6, Feb. 15, 1911.

occurring in moderate-sized, clear streams with a rocky bottom, avoiding the smaller tributaries.

3. *Truncilla arcæformis* (Lea).

Rare; only one example obtained. This was procured in the Big South Fork 2 miles above Burnside, Ky., and is rather peculiar in shape.

4. *Truncilla sulcata* (Lea). Pewee, cat's-claw.

Although this species seems to be pretty well distributed along a considerable stretch of the river, we obtained only occasional examples here and there along shore. Mr. Boepple found one in Caney Fork. It can probably be procured in larger numbers during low water. It is common enough to be pretty well known to the clammers, who call it "pewee" on account of its small size, or "cat's-claw" because of the peculiar clawlike structures on the marsupial expansion of the shell of the female.

5. *Truncilla haysiana* Lea.

Our collection of this species is rather small, but it is probably more common than the collection would indicate, as it is too small to bite on the crowfoot hook and is easily overlooked. Most of the examples collected had been killed and cleaned by muskrats. It is one of the handsomest of the *Truncillas* on account of its beautifully polished epidermis, and it has an unusually thick and solid shell for the genus. It is, however, too small for manufacturing purposes.

6. *Truncilla capsæformis* (Lea).

Fairly abundant in the Big South Fork, where nearly all the specimens had been killed by muskrats; in the main river we found it sparingly. Our shells are pretty badly eroded, very thin and brittle, with the marsupial expansion colored a dark green. The species is of no value for manufacturing purposes, being too small and thin.

7. *Truncilla florentina* (Lea).

Rare; the only specimen obtained was the dead shell of an old and very inflated female at Half Pone bar. In the autumn of 1910 Mr. Boepple found a specimen at Indian Creek bar. During low water probably many more could be obtained.

8. *Truncilla walkeri*, new species. (See fig. 1, frontispiece.)

A fine, large *Truncilla* with a honey-yellow epidermis and numerous capillary rays. Shell rather thin, elliptical in outline, much inflated in the females, only moderately in the males. Anterior margin projecting and evenly rounded, ventral margin strongly convex in the larger males, much less so in the females and smaller males; posterior margin oblique, but usually well rounded in both sexes; dorsal margin comparatively long, straight, or slightly curved. Umbones narrow and flattened. Anterior, lateral, and posterior slopes all well rounded; umboidal ridge flattened and indistinct, especially in the females. In front of this ridge the males have a broad and shallow sulcus; in the females the marsupial expansion is very pronounced, and is usually limited anteriorly and posteriorly by a deep and narrow sulcus. It is somewhat like that of *capsæformis*, but is considerably swollen, especially in the larger females, instead of being flattened, and does not project as strongly. Lines of growth smooth, distinct, and close together. Ligament long, thin, and light brown.

Interior: Pseudo cardinals large and thick, rather blunt and only slightly serrate or smooth; laterals long, high, thick, and slightly curved; anterior adductor scar slightly longer than wide, squarely truncated posteriorly; posterior scar large, deeply impressed, and squarely truncated anteriorly much as in *brevidens;* pallial impression fairly distinct, nacre milky white, thinner and quite iridescent posteriorly.

This species was quite abundant just below the ford of the East Fork of Stones River near Walterville, Tenn. We found here 140 shells, most of them on shore and recently killed by muskrats, and 1 or 2 living mussels. The smallest specimen (male)

measures 23.2 mm. long, 15.3 mm. high, and 8.8 mm. in diameter, the smallest female 31 mm. long, 19.9 mm. high, and 12.9 mm. in diameter. The largest male measures 57.7 mm. long, 42.7 mm. high, and 26.4 mm. in diameter, and the largest female 52.8 mm. long, 39 mm. high, and 23.9 mm. in diameter. There are 49 females, the others being males.

Walkeri, to Mr. Bryant Walker, one of our most eminent conchologists.

9. *Lampsilis ventricosa* (Barnes). Pocketbook.

Typical specimens of this species were obtained in two tributaries of the Cumberland, Harpeth River near its mouth, and Stones River, in the east fork at Walterhill and the west fork at Murfreesboro, Tenn. Just how common or widely distributed it is in the streams above mentioned is not known. The examples found were exceptionally fine and would make very good button shells.

In the main Cumberland *L. ventricosa* seems to be quite rare, its place being usually taken by the closely related *L. ovata*. Indeed, the distribution and relationships of *ovata* and *ventricosa* as found in the Cumberland and its tributaries are exceedingly perplexing. A few examples found near Clarksville, and a dwarf shell found at Elk Creek shoals above Dover, however, offered exceptional difficulties in classification, fitting in neither with *ventricosa* nor *ovata;* the male shell would perhaps fall on the *ovata* side of the dividing line; the females on the *ventricosa* side, if indeed not rather beyond the limits of the typical shell; these shells, both male and female, were rather too thick and solid for *ovata*. A marked feature of those at hand is a deep pink tinge of the nacre posteriorly, this tinge being pretty sharply limited to the posterio-dorsal area, a feature not common with either *ventricosa* or *ovata*.

The female shells are considerably more inflated than the males and have a peculiar flattening of the lower part of the posterior margin. One of the female shells was sent to Mr. Bryant Walker, who remarks concerning it as follows: "No. 5456 is a most remarkable shell. I have never seen a female *ovata* with such an enormous expansion. *Ventricosa* not uncommonly tends that way, but not to such an extent. * * * This shell is comparable only with *satur*. [A variety of *ventricosa*, according to Simpson; *satur* is *L. excavata*, according to Frierson.] This shell is either an extraordinary abnormality of *ovata* or is *ventricosa*. In view of the occurrence of *ventricosa* both in the Harpeth and Stones, I am inclined to refer it to the latter."

10. *Lampsilis ovata* (Say). Southern pocketbook; "grandma."

A fairly common species throughout the entire length of the Cumberland, more numerous in the upper portions and upper tributaries.

This species is one of the very few found in the Cumberland above the falls. Mr. Boepple obtained it at Pineville and Williamsburg and we found a few in the vicinity of the latter place and several examples just above the falls. Just below the falls it was abundant and common at the stations farther down. Associated with the typical form, which is relatively uncommon, is an aberrant form, more closely resembling *ventricosa*.

The specimens of this aberrant form were at first identified as *L. subovatus* Say, described and figured by Call.[a] On examination of the literature, however, there is no "*Unio subovatus* Say," and the name in Call's report is plainly a misprint for *ovatus*, the *Unio subovatus* Lea being an entirely different thing.

Say's original description of "*Unio ovatus*" is brief and the figure poor, but recognizable; it is probably better known from Conrad's description and excellent figure.[b]

The greater number of our specimens, however, differ considerably from the typical form. Beginning with the shapely, high-ridged clear yellow shell, which represents

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[a] Mollusca of Indiana, Twenty-fourth Annual Report of Geology and Natural Resources of Indiana, p. 481, pl. 39.

[b] Conrad, Monography, p. 4, pl. 2.

the species in its perfection, we have stained horn-colored examples, then deep-brown specimens and specimens with broad distinct rays. Inflated females are likely to have the ridge characteristic of *ovata* less markedly developed than males; in both sexes, however, there is a tendency for it to appear in all degrees of imperfect development until in some examples it is barely discernible. Indeed in one of our examples it is almost wholly absent, and we have a shell that, with the exception of purely individual features, can not be distinguished from a specimen of *L. ventricosa* from the upper Mississippi River.

Judging from the soft parts of a single gravid female examined, the bodies of *ventricosa* and *ovata* are quite unlike, the mantle flap of *ovata* showing a peculiar mottling quite different from the markings observed in the other species.

The variously modified forms of *ovata* are not only more abundant, but also more widely distributed than the type form. Just below Cumberland Falls most of the shells of this species are of medium size or smaller, nearly all are smoky brown, and several are well-rayed. At Indian Creek Bar brown and few-rayed individuals occur along with the typical form. At Goodall Island we found one with numerous distinct rays.

The shells of the Rock Castle River are different from the others and can be told almost at a glance. They are dark brown, longer and heavier than those of the other streams and have the posterior ridge rather low; *ovata* takes nearly the same place in the Cumberland that *ventricosa* does in the upper Mississippi.

We have always found *ovata* considerably inferior to *ventricosa* as a button shell, being thinner, smaller, and more brittle. The Rock Castle River *ovata* could possibly be used for buttons, but would furnish rather poor material. In the Cumberland the *ovata* is a rather valueless shell.

Call's experience with *ovata* is different. He says it is "one of the largest that are found in American waters; * * * it also attains a much greater size than Barnes's form (*ventricosa*)." This may be perfectly true for some rivers, as shells vary greatly in size and thickness in different streams.

11. *Lampsilis multiradiata* (Lea).

Rather rare in the main river and found almost entirely in its upper portion. Occurs typically in small, clear streams and often in lakes. It is more common in the tributaries than in the main river. The specimens from both forks of Stones River are beautiful shells, typical in form, not much eroded, and with a clear, white nacre. The specimens from Rock Castle River, Big South Fork, and the main stream depart more or less from the typical form, being unusually elongate and sharp-pointed posteriorly, rather thin, considerably eroded, and more or less stained or diseased in the nacre or in the teeth. On comparing the Red and Stones River shells with the others, a marked difference was noted in the cardinal teeth. In these typical specimens the large posterior cusp of the right valve pointed more or less anteriorly, while in the Rock Castle River specimens and most of the others it pointed more or less posteriorly. A few shells with intermediate characters in this respect were found, however.

12. *Lampsilis ligamentina* (Lamarck). Mucket.

This species is represented in the Cumberland chiefly by the southern mucket, *Lampsilis ligamentina gibba* Simpson, which differs from the typical form in being shorter and more compressed. The two forms grade into each other so imperceptibly that it is impossible to find the point of separation between them. In the lower part of the river it approaches more nearly the typical form.

The shell of the subspecies often has the epidermis more highly polished than in the type form, the nacre has more luster, and the valves are flatter and more uniform in thickness. The shells are therefore superior to those of the common mucket for manufacturing purposes and are sought after by shell buyers. Like the other forms of this genus this mucket carries its young in the gills through the winter. The

glochidia fasten readily to our common spiny-rayed fishes. Some gravid examples of this form were collected by Mr. Boepple in the autumn of 1910 from the upper Cumberland and sent to the biological station at Fairport, and though the mussels were dead the glochidia were still alive and attached themselves readily to fishes.

This is the most desirable form with which to stock the river and extensive plantings from the falls to the mouth would greatly increase its value as a mussel stream.

13. *Lampsilis orbiculata* (Hildreth).

Fairly common in the middle portion of the river, usually from 1 to 3 examples being found on each bed.

We were struck with the remarkable similarity between this species and the southern mucket, *Lampsilis ligamentina gibba*. About the only way to distinguish between them was by the bright orange shade of the epidermis, and usually orange tint of the nacre of *orbiculata*, and it is easy to understand Call's[a] remark that Dr. Hildreth and the earlier naturalists seem to have considered this shell as a variety of *Unio crassus* Say (= *Unio ligamentinus* Lamarck, short and thick variety found in the Ohio), but Call adds: "It certainly would seem to be a good species." Our own studies and comparisons showed them more distinct than appeared at first glance. The difference is most plainly seen in the female shells, which differ considerably from the males, being truncate posteriorly and short and well swollen postbasally. They are well represented by Say's[b] figure of *Unio abruptus*, and look somewhat like a compromise between the southern mucket and *L. ventricosa*. Ortmann[c] says that this species "is not at all related to *L. ligamentina* as Simpson thinks; but it belongs to the *ventricosa* group of *Lampsilis*, for it has a well-developed flap on the mantle edge."

L. orbiculata also very closely resembles *L. higginsii* which is more generally northern in its distribution, but the males of *higginsii* are shorter, more closely approaching *Obovaria ellipsis*. *Orbiculata* and *higginsii* are probably closely related.

This is a very good button species, but so uncommon that it is not much of an item in the trade.

14. *Lampsilis tæniata* (Conrad).

Rare; none at all were found in the Cumberland or in any of the tributaries except Stones River. It appears to be a species of small clear streams, and was found in the fine gravel at the edge of the water among the water-willows.

15. *Lampsilis picta* (Lea). Painted mussel.

Rather rare, and not taken by us in the main river. We found three in the Rock Castle River a few miles back from the Cumberland. Mr. Boepple, in the autumn of 1910, obtained it in the Big South Fork at Sloans Shoals, near Burnside. It is too small and thin to have any commercial value. Our largest example measures 61 mm. long, 33 mm. high, and 17.5 mm. in diameter.

16. *Lampsilis punctata* (Lea). Spotted mussel.

It is very like *L. picta* in color and outline, but differs in being more inflated and in carrying its thickness to the edge, so that its ventral margin is rather rounded and blunt, while that of *picta* is sharp. Both species are new to our collection. Mr. Bryant Walker, who identified them for us, called attention to the differences. The shell is thick anteriorly, but thins out rapidly behind the center. It has no commercial value on account of its small size, and most of our specimens are also badly eroded.

17. *Lampsilis perdix* (Lea).

Abundant in the Cumberland just below the falls. Mr. Boepple in 1910 found it as far down as Rowena and in the Obey River at Celina. It is common in Rock Castle and frequent in the Big South Fork.

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[a] Mollusca of Indiana, Indiana Geological Report, p. 493.

[b] American Conchology, pl. 17.

[c] Nautilus, vol. XXIII, no. 9, p. 119.

This species bears a general resemblance to an elongate flattish *L. ligamentina*. Unstained shells are easily recognized by the character of the rays, which are broken up and more strongly marked in places, making a series of heavy green blotches. Another peculiarity is the short lateral teeth, 1 in the right valve and 2 in the left; these are low and blunt, and separated from the cardinals by a wide interspace. Our older shells are badly eroded and so stained and discolored that the characteristic rays and blotches are absent. Such specimens can be recognized by the narrow border of latest formed nacre, which is yellowish or reddish and semitranslucent. Our shells usually have the nacre badly stained. Even if obtained free from stains they would make rather poor button shells, as they are somewhat brittle. In thickness they are about equal to a thin mucket. A few of the examples have brick-red pimply patches on the interior which probably indicate the presence of parasitic trematodes. No parasites, however, were noted.

18. *Lampsilis anodontoides* (Lea). Yellow sand-shell.

Rather uncommon, distributed chiefly through the central portion of the river, and never forming a large percentage of any of the beds. This species thrives best on sand bars in rather shallow water. It is generally confined to large streams. It is one of the most active of the mussels, responding quickly to changes in environment by moving about. This is by far the most valuable of the fresh-water mussels, the shells being generally used for export and in the manufacture of knife handles.

This species is easily propagated, the glochidia fastening readily to most of the common spiny-rayed fishes, such as sunfishes, bass, etc. On June 13 we found a number of gravid shells at Meeks Bar. Some sunfishes were caught, a tub was procured, and an infection made. The infected fishes were then liberated into the Cumberland in front of the blank factory at Clarksville.

19. *Lampsilis fallaciosa* (Smith). Slough sand-shell.

Rare in the Cumberland and not found in any of the tributaries. This species thrives best along shore in shallow water with a rather lively current and muddy bottom. Such conditions exist only in the very lowest portion of the Cumberland. From Kuttawa to the Ohio side sloughs are more common and the species is probably more abundant. The nacre of most specimens secured is stained. This is a first-class species for the manufacture of buttons, but it would be unprofitable to plant in the Cumberland because of the absence of favorable locations for its best development.

20. *Lampsilis recta* (Lamarck). Black sand-shell.

Rather common throughout the entire length of the river, but nowhere abundant. Many of the shells are badly eroded and stained; none are deep pink throughout, but are pale pink about the cardinal teeth and in the umbonal cavity.

Good white-nacred shells of this species are exceptionally excellent button shells, and where select stock could be obtained would be one of the most desirable species to propagate.

21. *Lampsilis lienosa* (Conrad).

The specimens we have are hardly typical and were with some doubt identified as this species. It is a small species of no commercial importance.

22. *Lampsilis vanuxamensis* (Lea).

The females of this species were gravid June 6. They are peculiar in having the marsupial expansion of the shell rather limited in area, not extending to the posterior end, but followed by a pointed extremity. In this localization of the shell they remind one somewhat of the *Truncillas*. The shells are small, red nacred, and of no value.

23. *Lampsilis trabalis* (Conrad).

Found only in the upper part of the river and its tributaries. The females are not markedly swollen posteriorly, but differ from the males in being shorter and broader.

Nearly all we found were dead shells, usually badly eroded at the umbones. Mr. Boepple found the species as far down as Cloyds Landing and in the Obey River at Celina. As found, the epidermis is generally jet black, usually due to the shells being stained. On being cleaned with acids they exhibit beautiful rays. This is a small species of no commercial importance.

24. *Lampsilis parva* (Barnes).

Rare; none at all in the Cumberland; indeed it has not been reported from that river. But we obtained one specimen in the East Fork of Stones River at Waterville. This was a slender shell; length 27 mm., height 15 mm., width 11 mm. Nacre beautifully white and iridescent.

25. *Lampsilis glans* (Lea).

Rare; none at all in the Cumberland; 10 specimens from the tributaries. Those found were in gravel in shallow and rather swift water. In general it prefers quiet streams with muddy banks and burrows in the firm mud. It is also frequently found in lakes.

One of the smallest of our species; too small for commercial use, and with a rich purple nacre. In one specimen, a female found in Roaring River, the peculiar glands of the mantle, small white cylindrical objects on each side, were protruded and were undergoing spasmodic movements.

26. *Lampsilis alata* (Say). Pancake; pink hatchet-back.

While not a rare species in the Cumberland, this is not especially common. In a few of the beds it is entirely absent, and in many only one or two shells were found. It never exceeded 4 per cent of the catch of any of the beds, and is usually less than one. It is well distributed throughout the entire river. It prefers rather deep water and a soft, muddy bottom. The shell, on account of its thinness and red nacre, is of no value whatever.

27. *Lampsilis gracilis* (Barnes). Paper-shell.

Frequent enough to be a rather familiar species among clammers, but not so abundant as to be a nuisance. It has much the same distribution as *alata*, but is less common. We usually obtained only 1 or 2 from a bed. Our shells are rather badly worn at the umbones. As this thin-shelled species is of no value whatever, but readily catches the mussel hooks, it proves to be a nuisance when present in large numbers where clamming operations are being carried on.

28. *Lampsilis lævissima* (Lea). Paper-shell.

Rare; only one specimen found in the Cumberland; this was at Meeks Spring Bar. It seemed to be more common in the Harpeth. This species closely resembles *L. gracilis* in general appearance, but has, among other distinguishing features, a beautifully polished epidermis. Our examples have a number of peculiar rays, consisting not of a different pigmentation of the epidermis but of a series of short, finely wrinkled lines.

29. *Lampsilis leptodon* Rafinesque.

This fragile, thin-shelled species is rare in the Cumberland. The only examples obtained were collected by Mr. Boepple at Albany and Cloyds Landing in the autumn of 1910.

30. *Medionidus conradicus* (Lea).

This species is confined chiefly to small streams. It is exceedingly abundant in the Rock Castle River at Livingston, Ky., the sandy bottom being almost covered with these animals, which showed up as narrow black lines, the mantle and exhalent and inhalent apertures being thin and black. It is also abundant in Roaring River.

In the Cumberland we found it just below the falls and at Salt Lick Island. All the shells were badly stained and eroded, and for this reason, as well as on account of its small size, it has no commercial value.

31. *Obovaria retusa* (Lamarck). Golf-stick.

Although we obtained only a few specimens of this species, scattered valves were frequently found along shore, and there is reason to believe that it is considerably more common than our small collection would indicate, although by no means abundant anywhere. In the Cumberland it attains a rather large size, our largest shell measuring 68.5 mm. long, 74.5 mm. high, and 46.9 mm. in diameter. It is a heavy and solid shell, but the deep purple of that portion of the nacre within the pallial line makes it valueless for buttons. All our shells are somewhat eroded at the umbones. Two of them are considerably less retuse than the others, somewhat approaching *O. circulus* in this respect. All have the epidermis somewhat paler posteriorly, but not so markedly so as is usually the case with *O. circulus*.

32. *Obovaria circulus* (Lea).

Rather common in the main river from Burnside to Half Pone Bar. This species produces too small a shell to be of much importance to the button trade. The larger shells would furnish two or four blanks apiece, and are excellent both as to material and thickness. The nacre seems to be unusually durable and retains its firmness and luster long after others have become chalky.

33. *Obovaria ellipsis* (Lea). Missouri niggerhead.

This species is chiefly northern in its distribution and does not attain large size in the Cumberland. Although in its shell characters it bears considerable resemblance to some of the Quadrulas, especially the niggerhead, *Q. ebena*, it is really more closely related to the sand-shells. Where it attains large size it is an excellent button shell and would be a fine species to propagate, but the reduced size of the shell in the Cumberland indicates that the conditions there are not favorable. We found gravid examples above Clarksville early in June.

34. *Plagiola securis* (Lea). Butterfly.

This species is fairly common throughout the entire length of the river below the falls, and, while not abundant enough to make a large percentage of the shells taken for commercial purposes, it makes a fair sprinkling in most of the clammers' piles. It seems to thrive exceptionally well in the Cumberland and is more common here than in most rivers. The shell, especially of young to medium-sized, well preserved males, is one of the most attractive among the Unionidæ. In the Cumberland there is a marked difference between the shells of the males and females, that of the former being flat and compressed and of rather uniform thickness, while those of the females are much more tumid and swollen. The measurements of a fairly typical male (F5086) of medium size are 54 mm. long, 44 mm. high, and 21.1 mm. in diameter, while those of a tumid female of about the same length (F2660) are 55.3 mm. long, 45 mm. high, and 33.7 mm. in diameter. In the lower part of the river the nacre is somewhat spotted, but upstream the shells are free from stain. On account of its excellent luster, flatness, and uniform thickness, this is an excellent button shell, the males being much superior to the females.

Females were found gravid May 29, and were in the height of the breeding season from about June 3 to 16. This would be a very valuable species with which to stock the river.

35. *Plagiola elegans* (Lea). Deer-toe.

This species is not as common nor as widely distributed as the preceding. Large shells can be used in the manufacture of buttons, but the great majority are too small. The largest example found was a single valve 59 mm. long, picked up at the foot of Gowers Island. The beautifully tesselated green markings on the epidermis make it an attractive shell when perfect.

36. *Plagiola donaciformis* (Lea).

This dainty little species is more limited in its distribution in the Cumberland than either of its two relatives. A peculiarity of the species at Half Pone Bar was the frequent unfolding of the anterior ventral portion of the shell, the inner layer being folded back against the rest, as if by some injury. The specimens found here were unusually thin-shelled and frequently had the nacre well tinged with pink. Perfect specimens of this shell are among the most attractive to be found in the Unionidæ, but the Cumberland examples, especially those from Half Pone Bar, are badly worn at the umbones, so that even small specimens have the appearance of age. This is one of the smallest of the mussels—too small to be of any use for manufacturing purposes.

37. *Cyprogenia irrorata* (Lea).

This species is of rather infrequent occurrence in the Cumberland. We found none at all in any of the tributaries, and usually found only one or two on each bed examined. The species seems to inhabit rather deep water, since we never saw any crawling around on the shallow bars. Most of the examples are rather small, and some have a shallow sulcus running over the middle of the disk from the umbonal region to the postventral margin.

A very solid shell, but of little commercial value, as it is rather brittle and has pink tips. The few shells that get into the clammers' piles are generally worked up, however.

38. *Obliquaria reflexa* (Rafinesque). Three-horned warty-back.

One of the most common shells of the river, and found throughout its entire extent. Although a rather small shell, this is so thick and solid that it is used to a considerable extent in the manufacture of buttons, each valve furnishing one or two small blanks. The species has a long breeding season, spawning through almost the entire summer, the young being extruded in white cylindrical masses. Some of these spawn masses were seen lying on the gravel at Half Pone Bar June 16. Shells of females are somewhat fuller anteriorly than the males and can usually be distinguished after some practice. The Cumberland specimens are not so beautifully rayed as those from the upper Mississippi.

39. *Ptychobranchus phaseolus* Hildreth. Kidney-shell.

Scattered in the upper Cumberland from the falls down to Half Pone Bar. Although this is a species of rather wide distribution, especially southward, and is by no means a rare shell, it is never found in great numbers or making a large per cent in any bed. The clammer rarely gets over a half dozen or dozen to the ton; the nacre is white, with a soft satiny luster; the shape is nearly that of *Unio gibbosus*, and the species would probably make a fair button shell.

40. *Ptychobranchus subtentus* (Say). Fluted kidney-shell.

This species in Simpson's Synopsis is placed in the genus *Medionidus*. Dr. Ortmann, however, has removed it to *Ptychobranchus*, and, although we have seen no gravid examples, we are inclined to follow him in this regard on account of the close resemblance of the shell to that of *P. phaseolus*, differing from that species chiefly in its thinner shell, greater inflation, and the presence of costæ on its posterior slope. On account of its small size and its thinness it has no commercial value.

41. *Dromus dromas* (Lea). Dromedary mussel.

In the main river this shell is of occasional occurrence from Mill Springs Bar, in the upper river, down to Red Rock Bar, below Clarksville, Tenn. We usually obtained one or two specimens at a station. The shells are rather heavy and inflated, though the hump on the disk, which is characteristic of the species, is not nearly as prominent as in some specimens from the Washington collection obtained by Mr. Boepple in the Clinch and Holston Rivers. Some of the shells are beautifully rayed, especially

anteriorly, but the greater number are too deeply stained for the rays to show. In the living animal the mantle is prettily rayed.

The shape, size, and solidity of the shell of this species make it suitable for the manufacture of buttons, but unfortunately it is too brittle and hard, resembling *Pleurobema æsopus* in this respect. About one-third of the shell, moreover (the tip part), is of a pink tinge, which runs entirely through the shell, making it of no value.

42. *Dromus caperatus* (Lea). Fan mussel.

The examples of *Dromus* obtained in the Big South Fork of the Cumberland differ from those found in the main river by being considerably flatter, with the hump on the disk less pronounced or nearly absent. These flattened shells represent the species *caperatus* (Lea). Our series indicate that the two forms run together. In young specimens, before the step-off is formed, it is doubtful if *dromas* and *caperatus* could be distinguished.

From what has been said concerning the relationship between this and the preceding species it may be readily inferred that this species also, from a commercial standpoint, is valueless.

43. *Strophitus edentulus* (Lea). Squaw-foot.

We found only a few examples of this species. It has a fragile shell, which disintegrates quickly and is probably more common than our small collection would indicate. Mr. Boepple found it at Pineville, the highest point at which the river was examined. It is a species which occurs in all sorts of situations—in both small and large streams and in lakes. Two of our specimens have a pink-purple nacre; in the others it is of a yellowish cast. The species is of no value on account of its thin, brittle shell. It is exceedingly variable, and presents many puzzling forms. According to Mr. Bryant Walker our specimens represent the form *shaefferiana* Lea.

44. *Anodonta imbecillis* (Say).

The distribution of this fragile, beautiful species is almost identical with that of *A. grandis*. Of the two found in Haynes Lake one was gravid (Sept. 3). The glochidia are rather large, chestnut-shaped in outline, brown, and fill the entire outer gills. The species remains gravid through the winter. The Haynes Lake shells contained several *Atax* apiece.

45. *Anodonta grandis* (Say).

This species was not found in the main river. In general, conditions throughout the whole Cumberland system are not favorable to its development. The small tributaries are too swift and rocky, and the Cumberland itself is lacking in the quiet, muddy sloughs in which *A. grandis* can thrive. The only river examples we found were in the Stones River, a few in the East Fork near Walterhill, Tenn., and several in the West Fork near Murfreesboro. At the last-mentioned place it had apparently once been abundant in the vicinity of the railroad bridge, where it had thriven in the mud of the deep, quiet pools among the water-willows. A number of shells, recently killed by pearlers, were lying on the bank. These were large, heavy shells, unusually thick for the species, and varied considerably in shape, some of them being markedly elongate.

In Haynes Lake, a shallow, muddy pond below Clarksville, *Anodonta grandis* was fairly abundant, and about 30 examples were secured. These were more shapely, of a larger size than those from Stones River, and much thinner. They are indeed the largest and finest examples of the species we have ever seen and represent the form *gigantea* Lea. The largest example measured 201.3 mm. long, 112.5 mm. high., and 82.3 mm. in diameter. These shells are peculiar in having two distinct colors of nacre, about half of them being dark purple, while the other half are a beautiful, lustrous, creamy white. The reason for this difference is not apparent; parasites are almost entirely absent.

46. *Lastena lata* (Rafinesque).

Very few examples seen in addition to those enumerated in the table. Mr. Boepple obtained it at Burnside, Albany Landing, and Cloyds. Its apparent scarcity is due in part to its habits. It can not be caught on the crowfoot hook, but must be obtained by wading, and is best secured when the water is low and clear. The species appears to prefer gravel bars with a rather swift current. The shell is beautifully polished and rayed, and is very thin, cracking easily when exposed to the air. Our examples are rather badly eroded.

47. *Anodontoides ferussacianus* (Lea).

Rare; only a few specimens found. A thin, fragile *Anodonta*-like shell of no commercial value.

48. *Pegias fabula* (Lea).

A rare species of which we found only two living and four dead specimens in the Rock Castle River near Livingston, Ky. They are quite small, the smallest measuring 22.7 mm. long, 15.5 mm. high, and 11 mm. in diameter, and the largest 31 mm. long, 20 mm. high, and 14 mm. in diameter. In their perfect condition these must be very attractive little shells, but our specimens are very badly eroded.

49. *Symphynota costata* (Rafinesque). Fluted shell.

Occasional in the upper Cumberland from the falls down to the foot of Gowers Island. Occurs typically in moderately small streams and appears to be entirely absent from the lower stretches of the Cumberland. It is rather common in the various tributaries. The Stones River shells were exceptionally thick and heavy, and bore a goodly number of dead or soft pearls.

On account of its yellow nacre and tendency to crack this species is of no use in the manufacture of buttons.

Several of our specimens have numerous deep wrinkles extending ventrally over the posterior half of the disk. One is unusually shortened, truncate posteriorly and produced forward, and has well-marked rays, while another medium-sized shell from a mile below the falls is unusually elongate.

50. *Symphynota complanata* (Barnes). White heel-splitter.

Rare; only two examples of this species were found in the entire Cumberland. The shells were small, thin, and badly stained. These were obtained on Red Rock bar below Clarksville. Fragments of large strong shells were found in the Harpeth River. This species thrives in a muddy bottom and is often found in sloughs. Under especially favorable conditions it produces a fairly thick large shell which furnishes usable button material, but the Cumberland shells of this species have no value.

51. *Alasmidonta minor* Lea.

Confined to the upper river and tributaries. So far as our experience goes, this species is found typically in small streams, living in the sand between rocks. It may live along the border of large streams, but on account of its small size would be easily overlooked. Most of the specimens found had been killed by muskrats. The shells were all badly eroded and so deeply stained that the characteristic rays were obscured and the nacre rather badly stained.

This species is always too small to have any commercial value. Our smallest example measures 17 mm. long, 11 mm. wide, and 6 mm. in diameter, and our largest 45 mm. long, 28 mm. wide, and 18 mm. in diameter.

This species closely resembles *A. calceola*, a better known and more widely distributed species, but has a heavier shell and teeth and darker epidermis, and is somewhat flatter and longer.

52. *Alasmidonta truncata* B. H. Wright. Elk-toe.

This is not a common mussel in the Cumberland and is, generally speaking, a species of rather small streams and the upper courses of larger rivers. All the shells found were dwarfed, very thin and eroded, and with the epidermis rather badly stained.

When well developed this is an attractive shell, but it is always too thin and fragile to have any commercial value.

According to Mr. Bryant Walker, there is no difference between this and *A. marginata* Say, and our thin dwarf specimens lend probability to this view. As we have seen but few *marginata* we have no means of comparing them. As Simpson has separated the two forms, however, and ours are within the geographic range of *truncata*, we retain for the present Simpson's name.

53. *Margaritana monodonta* (Say). Spectacle case.

Occasional from Snows Island, where we first encountered it, as far down as Dover and perhaps beyond. The shells are fragile and break and crack easily, and disappear soon after dying. The species has no commercial value.

54. *Unio gibbosus* Barnes. Lady-finger; spike.

Unlike *Unio crassidens* this species is not especially abundant in the Cumberland. Though distributed throughout the entire length of the river, at many stations only a half dozen specimens were found, and nowhere did it rise above 4 per cent of the entire catch. In the Cumberland above the falls it is about the only species found. In the Clear Fork at Jellico, Tenn., and Savoy, Ky., it was abundant, forming about 90 per cent or more of the entire mussel population, and numerous dead shells recently killed by muskrats were found along shore and at the base of the water-willows.

These Clear Fork examples were all small dwarf shells with a rather pale nacre. They approach a well-marked form found in Green River, Ky., and other southern streams. The Clear Fork flows through sandy and shaly country and the water may be too deficient in lime to promote good shell growth. Immediately below the falls we encountered the normal full-grown form which is the one of the main river.

Gravid examples of this species were found during the entire summer.

55. *Unio crassidens* Lamarck. Elephant-ear.

Exceedingly abundant, especially in the upper part of the river. It is a species of large streams, and we did not find it in any of the tributaries nor above the falls. In the upper part of the river this shell is a decided nuisance, forming a large part of the clammer's catch, taking much of his time and labor and yielding little in return. It is generally known as the "pink," and clammers, on their prospecting cruises, note down the percentage of "pinks" and "whites," from which to judge the value of a bed. It is the great abundance of this species that makes the section of river from Burnside to Celina unprofitable clamming, and the problem of making this stretch a valuable clamming ground consists as much in the reduction of this species as in the increase of valuable kinds.

U. crassidens exhibits considerable modification as one ascends the Cumberland. In the lower stretches of the river most of the shells are the rather elongate form, which seems to be most common the country over. As one advances upstream these elongate shells gradually give way to a short and chunky variety.

The shells from Half Pone bar and a few from Mill Springs and Salt Lick bar show rather well-marked rays; most of the others are rayless.

Occasionally shells with the nacre very pale or almost white are found. These are called "white-pinks" and are acceptable to the buyer. Even the more or less markedly pink ones are beginning to be used, but there is little demand for them and they always bring a rather low price. The shells work up exceptionally well, being soft and free from grit.

While at Clarksville we were informed that the superintendent of one of the smelting furnaces along the river had been trying cull shells as a flux and found them satisfactory. It is doubtful whether this utilization, however, will make an important market for them.

56. *Pleurobema clava* (Lamarck). Club-shell.

Generally rare, and not found at all below Burnside. The shells are all badly eroded and discolored; one of them is unusually elongate, and several show a rather well-marked, broad and shallow furrow in front of the posterior ridge. We have usually found this species most abundant in small streams, and this may explain its absence from the greater part of the Cumberland. It is a rather handsome shell but too small to have any commercial value.

57. *Pleurobema crudum* (Lea).

This species does not appear to be common or widely distributed. All our examples are rather small shells, somewhat resembling a much-flattened *Quadrula subrotunda*, but with the epidermis of a brighter yellow and the rays quite distinct, well defined, and broken up into blotches.

58. *Pleurobema æsopus* (Green). Bullhead.

We did not see many examples of this species in the Cumberland, but it is common enough to be well known among the clammers. In the upper Mississippi it is called "bullhead" or "sheepnose," and is used in button manufacture, although it is ranked as a rather low-grade shell on account of its brittleness. In the Cumberland it is so hard and flinty that no attempt at all is made to cut it as it breaks saws. The clammers call it "clear profit" because they are "the only ones who get anything out of it." A small example obtained at Half Pone bar was of a beautiful yellow color; the older ones are brown.

The systematic position of this species is in doubt. It seems to stand between *Quadrula* and *Pleurobema*. Simpson [a] was not certain as to where to place it, having seen only one example gravid, and it with the gills partly filled. At the biological station at Fairport one was found with only the inner gills filled with glochidia and another with all four. Sterki [b] has found glochidia in all four gills. Usually, however, only the outer gills are used as a marsupium.

59. *Quadrula tritogonia* (Barnes). Buckhorn; pistol grip.

This is the *Tritogonia tuberculata* of Simpson's Synopsis. At the time the Synopsis was written the gravid female was not known. The shell stood pretty much by itself, and Mr. Simpson, who was struck by certain peculiar features, especially the noteworthy difference between the male and female shells, formed a separate genus for it. Since the discovery by various students that it bears young in all four gills, there is a general tendency to place it in the genus *Quadrula*, and Dr. Ortmann, who was the first to propose the shift, suggested the name given above. The species is quite aberrant; none of the other *Quadrulas* resemble it very closely, the nearest approach being some of the elongate *Quadrulas* such as *cylindrica*, especially the rough subspecies *strigillata* or *Quadrula trapezoides* from the south. The marked difference between the males and females is unique among any related forms and entitles it at least to subgeneric rank.

This species is not rare in the Cumberland and was obtained in small numbers at most of the stations from the falls down to Dover. Our specimens are mostly of medium size and a number have the nacre rather badly stained. They exhibit but little variation among themselves or from the form as generally known. The nacre of all but two is white; in these two, obtained near Clarksville, it is pink.

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[a] Synopsis of the Naiades, Proceedings of United States National Museum, vol. XXII, p. 745 and 764.

[b] According to Ortmann, Nautilus, vol. XXII, no. 10, Feb., 1909, p. 100.

Where it attains its best development, the buckhorn is an excellent button shell, indeed one of the best. It does not find the most favorable conditions for growth and development in the Cumberland, however. It is not as yet amenable to propagation on a large scale, as it is but rarely that one finds gravid examples.

60. *Quadrula perplicata* (Conrad).

The plicate *Quadrulas* of the Cumberland, especially the middle portion of the river, are rather peculiar shells, lying somewhere between typical *plicata* and *undulata*. The beaks are too low and flattened for *plicata* and the shells are too heavy and a trifle too inflated for *undulata*. A marked feature about them, in addition to their general rotundity of outline, is the fact that they usually taper to a point posteriorly. The clammers call them the "round-lake," and say that in proper conditions they are good pearl bearers. The folds are few and gently rounded. Mr. Bryant Walker, who examined them, is of the opinion that they are *perplicata*. We obtained some good specimens at Meeks Spring bar. Our largest measures 119 mm. long, 86 mm. high, and 56 mm. in diameter. At Half Pone bar a particularly interesting and instructive lot of young shells were obtained. These are inflated and rotund, approaching a spherical form with a greenish epidermis. Though quite small, they are so worn at the umbones that they look like old shells and no beak sculpture is shown. The smallest measures 17 mm. long, 15 mm. high, and 10 mm. in diameter. Farther up the river, at Cloyds Landing, this shell approaches *undulata*, while in Stones River, near Murfreesboro, the real *undulata* is found.

The shells are thick, solid, and heavy, but the nacre is spotted and they form rather poor button material. If they could be obtained free from spots, they would have a good market value.

61. *Quadrula undulata* (Barnes). Three-ridge or blue-point.

Beautiful examples of this species are common in the West Fork of Stones River near Murfreesboro, Tenn. It is also found in the East Fork near Walterhill. The young examples are yellowish brown, well compressed, and entirely free from erosion, so that the umbones show the sculpture very plainly. This consists of four or five high, coarse ridges, the first-formed ones crescentic, the older ones gradually vanishing backward until the last one is a short, low tubercle. The undulations are deep and crossed by numerous small furrows. A noteworthy feature of these shells is the great distance of the pallial line from the margin. The shells are somewhat spotted, but the spots are small and they would yield a fair amount of good button material.

62. *Quadrula heros* (Say). Washboard.

This is a species of large rivers. It is not found in the upper part of the Cumberland, but is abundant in the lower river. The first we saw was at the Mill Springs bar.

This species bears the largest and heaviest shell of the North American Unionidæ. It becomes rather large in the Cumberland, but not as immense as in the Wabash and some parts of the upper Mississippi. Our largest shell measures 162.8 by 115 by 62.4 mm. Our collection exhibits little variation. From the unusually large number of small examples seen it appears that the species is exceptionally prolific in the Cumberland, especially about Half Pone bar and Owl Hollow bar above Clarksville. All our examples are somewhat eroded at the umbones, but only two or three badly. The young examples are noteworthy for having the finely waved broken sculptures, characteristic of the umbones of the older specimens, over the entire disk and the plications rudimentary or only faintly developed, so that they do not closely resemble the old.

We found no gravid examples. They are indeed very rarely found, and nothing is known at present about its spawning habits or as to what fish acts as host to the embryos.[a]

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[a] Since the above was written investigators at the Biological Laboratory at Fairport have thrown considerable light on the breeding habits, hosts, etc., of this species.

In some rivers, as parts of the Illinois, this shell does not become stained early, and the younger shells furnish excellent button material. For the common run of buttons this shell is becoming one of the most important species, as its large size and expanse allows it to be worked up readily into buttons of various sizes, and the stains can be bleached out or the buttons "smoked" or artificially dyed. In the Cumberland the nacre becomes badly stained, even when the shell is quite small, and the washboards are always sorted out and sold separately as low-grade shells, bringing but $2 to $5 per ton when first-grade shells are bringing $6 to $8.

But few parasites were found, and we have as yet no clue to the cause of the discolored spots on the nacre. These spots are usually circular in outline and frequently have what appears to be a foreign body in a small raised pustule at the center. The fresher stains, or those near the surface, do not really permeate the nacre, but are composed of a flat hornlike skin overlying it and can be softened by acids and scraped away from the unstained shell beneath. The older, duller stains are doubtless the same thing covered by layers of nacre.

Many of our specimens are interesting as showing with unusual clearness the path, during growth, of the posterior adductor muscle scar, the anterior border of which is dimly defined, while straight converging lines from the dorsal and ventral borders of the scar lead up into the umbonal cavity. One of our specimens has a pinkish nacre.

63. *Quadrula cylindrica* (Say). Rabbit's-foot.

Occasional to abundant in the upper part of the river. On account of its narrow cylindrical shape it is of little value for buttons; the nacre, moreover, is frequently diseased and stained. The flesh is usually orange yellow and the gills, when filled with glochidia, markedly so. Some of our examples are well covered with small tubercules over the anterior portion of the disk, approaching the subspecies ***strigillata.***

This is a rather active species, the most active of the *Quadrulas*. Its elongate form, in which it differs markedly from its nearest relative, *metanevra*, and indeed from all Quadrulas in general, may be an adaptation to an active life.

64. *Quadrula metanevra* (Rafinesque). Monkey-face.

This well-known button species is fairly common. A few were to be found at nearly every station, clam pile, or mussel bed. It was not abundant enough, however, to form more than a sprinkling among the shell piles, and it cuts a rather small figure in the button industry of the Cumberland. On account of its luster and solidity it is very acceptable to the manufacturers. It would not be worth propagating, however, as there are plenty of better species. We found one example of this species gravid on the last of May.

65. *Quadrula tuberosa* (Lea).

Rare and collected only in the upper river. In the autum of 1910 Mr. Boepple obtained it at Sloans Shoals in the South Fork near Burnside, at Selfs Bar, and at Cloyds Landing.

66. *Quadrula fragosa* Conrad.

This species is occasional, and in some places abundant, in the lower Cumberland. It does not appear to "bite" readily on the crowfoot hook and the few examples taken by clammers are apparently no indication of its abundance. Small mussels of this species are a favorite food of the muskrat. Of a large pile of shells cleaned out by these rodents near Meeks Spring Bar, nearly all were this species and *Obliquaria reflexa*, although other mussels appeared to be common in the vicinity.

This species is very similar to *Quadrula lachrymosa* (Lea) and the differences between the two are difficult to express either by description or figure. It is somewhat more square-cornered, more inflated, and the tubercles on the posterior slope are more markedly arranged in rows, forming costæ. This species does not become as large as

Q. lachrymosa and is of little commercial value. We found gravid examples below Kuttawa May 17 and at the foot of Dover Island May 29. All four gills serve as marsupia and are thick and pad-like.

67. *Quadrula pustulosa* (Lea). Warty-back.

Common throughout the entire length of the river. Our shells exhibit a marked uniformity in general appearance, being rather inflated with only a moderate number of low tubercles. A few shells found a mile below Cumberland Falls are almost entirely smooth. With the exception of the Half Pone Bar specimens most of the shells have a cloth-like epidermis.

The warty-backs of the Cumberland are as a rule rather undersized, and their inflated form is something of a disadvantage, so that they are not as valuable as in some other streams.

68. *Quadrula cooperiana* (Lea). Cumberland pigtoe.

Not rare in the Cumberland. The proportions of the shell vary considerably, some being higher than long and others longer than high. The older examples are generally more elongate than the younger. The shells also vary somewhat as regards degree of inflation. One of the young shells has the epidermis faintly rayed, the others are eradiate. Three of the shells have the epidermis polished and shining; in the others it is dull. The nacre is sometimes a pale suffused pink within the pallial line, but in the majority of cases it is pure white. This is regarded as a very fair button shell. In appearance it lies intermediate between *pustulosa* and *granifera*. From *granifera* it can always be distinguished by the color of its nacre. It is usually longer and flatter than *pustulosa*, and there are peculiarities of epidermis, disposition of pustules, and shape of teeth that taken together help to separate them. They can always be separated if in the flesh, as *cooperiana* always has an orange-yellow flesh. The ova which fill the gills are bright yellow.

We found only two examples gravid, early in June. The developing ova were borne in the outer gills and gave it a sulphur-yellow color.

Dr. Ortmann removes this species from the genus *Quadrula* and places it in *Pleurobema;* he remarks that it is closely related to *P. æsopus*. We are rather favorably inclined to this view, but in view of the fact that these two genera need a thorough revision and may possibly run into each other we prefer at present to leave it where Simpson placed it, among shells that it strongly resembles.

69. *Quadrula rubignosa* (Lea). Wabash pigtoe.

This species was found nowhere except in the East Fork of Stones River at Walterhill, Tenn. The shells show very little difference in general appearance, except that in the smallest the posterior ridge is poorly defined, and one of the medium-sized examples is somewhat more rounded, and has a lower posterior ridge. Large examples of this species make a moderately good button shell.

70. *Quadrula undata* (Barnes). Pigtoe.

This, as Bryant Walker has shown,[a] is the proper name for the *Quadrula trigona* (Lea) of Simpson's Synopsis. Ortmann[b] regards it as a subspecies of *Q. rubiginosa*. Though we have observed great variation in this shell, we have never seen any transition forms between the two species. It is rare in the Cumberland and the shells are rather small, measuring about 45 mm. long, 43 mm. high, and 25.7 mm. in diameter. The epidermis is clothlike and finely striate. The flesh is orange, in which respect it approaches *rubiginosa*.

An example procured at Linton, Ky., had a dorsal baroque, and the mantle contained 4 marginal distomid cysts, a parasite which is especially frequent in this species.

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[a] Nautilus.

[b] Nautilus, vol. XXIII, no. 9, Feb., 1910, p. 116.

Where the pigtoe is found in abundance, as in some parts of the upper Mississippi, it is used quite extensively in the manufacture of buttons. It yields only a few blanks per shell, however, and would not be a desirable species to propagate.

71. *Quadrula obliqua* (Lemarck). Ohio River pigtoe.

This is the most abundant, and, on this account, the most important, commercial species in the river, especially in the central portion, where it greatly exceeds any other species in number.

The Ohio River pigtoe is a very good button shell. It is inferior to the niggerhead, both in luster and form, the sulcus on the side and the thinning out at the tip making it of unequal thickness; but, with the exception of the niggerhead, it is one of the best species.

It is a rather prolific breeder. We found more gravid specimens of this than of any other species. The height of the spawning season is during the latter half of May and the earlier half of June. Occasional examples, however, may be found during the entire summer. Of five examined at Beasleys Shoals August 9, four were gravid. The portion of the gills used as marsupia varies greatly in different examples; it may depend upon the amount of ova fertilized and upon the age of the mussel. In some of the mussels the lower half of the outer gills are filled; in other cases the entire outer gills and quite frequently all four gills. Occasionally three gills, the two outer and one of the inner, contain eggs or young. There are no well-marked sulci between the conglutinates, which are rather thin and flat, resembling the seed of the green cucumber in general appearance. They are peculiar in that, when viewed from the side, they present a wavy appearance. This, so far as we know, is found only in the present species and enables one to distinguish the conglutinates even when found free from the animal. The wavy appearance is due to little pits in the anterior and posterior faces. A conglutinate of this species was found lying on the gravel bar in shallow water at Half Pone Bar June 16; the species was therefore spawning at that date.

Dr. Ortmann has removed this species from the genus *Quadrula* and placed it in *Pleurobema*. All the examples he had examined up to that time had glochidia in the outer gills only. According to the data given above, its transfer to *Pleurobema* seems hardly advisable until the whole group is more thoroughly revised.

72. *Quadrula coccinea* (Conrad).

What appears to be an oblique form of *Quadrula coccinea* occurs rather frequently in the Big South Fork opposite Parkers Lake Station. Similar forms occur in the upper Cumberland down as far as Tear-coat Bar. In the main river these forms run into others in inextricable confusion, and nothing definite can be said about this species from the material at hand.

Dr. Ortmann is of the opinion that *Quadrula coccinea* is a variety of *Q. obliqua*. In some of the northern rivers it seems to be a fairly constant and well-defined form.

73. *Quadrula solida* (Lea).

Only occasional. We obtained a few, principally at Indian Creek Bar. The shells were not typical and differed considerably from those found in the upper Mississippi. The sulcus is very faint, and the nacre is not white but varies from pale rosy to purplish red.

74. *Quadrula plena* (Lea).

This appears to be a rare species in the Cumberland, and we obtained only a few scattered shells. They are all small and resemble very closely a much-shortened *Q. obliqua*, the compressed posterior portion being very short and the height of the shell being very great, considerably exceeding the length. The nacre is pale rosy.

Mr. Boepple obtained this species in 1910 from Fords Island down to Martinsburg in the upper part of the river.

75. *Quadrula pyramidata* (Lea).

Rare; we obtained a few examples in the vicinity of Mill Springs Bar. Our specimens have a broad furrow on the posterior half of the shell and differ from *Q. obliqua*, which they otherwise much resemble, by the umbones projecting far forward. They agree quite closely with Conrad's figure and description[a] of *Unio mytiloides* which Simpson regards as a synonym, except that the epidermis of our shells is black rather than brown and umbones are badly eroded.

This is a very perplexing species. The extreme form, which, if it were only constant, would represent a very well marked and easily recognizable species, resembles an immensely overgrown *Pleurobema clava* in general appearance. Such specimens are rare; we have a few in the Washington collection. Our shells represent a sort of intermediate form between that and *Quadrula obliqua*.

Mr. Boepple obtained examples from several stations in the upper river, to which portion it is apparently pretty well confined.

76. *Quadrula subrotunda* (Lea).

The young of this species have a general resemblance to *Quadrula ebena*, the niggerhead, but can be distinguished by their polished epidermis and broken rays near the umbones. We obtained only a few examples of these easily recognized shells.

What is probably the adult of this species is occasional through the length of the river. We have not been able satisfactorily to connect the small shells with the large ones through a perfectly unbroken series, but up to the present can think of no better disposition to make of them. They have a black epidermis, with the umbones generally more or less eroded, and very much resemble an elongated *ebena*. These large shells are fairly common in the upper stretches of the river. A peculiarity of the old mussel is the rich orange color of the soft parts. At the blank factory at Clarksville they are known as the "long solid" and are regarded as one of the best button species of the river. None were found gravid. If they were to prove amenable to propagation, they might be profitable to plant in the upper part of the river and in similar situations where *ebena* would not thrive.

77. *Quadrula ebena* (Lea). Niggerhead.

This important commercial species, which is generally regarded as the producer of the most valuable shell for the manufacture of buttons, is absent in the upper Cumberland, and is abundant enough to be of considerable commercial importance only in the lower stretches of the river.

The niggerhead is a deep-water shell and is rarely found in small rivers, or in such mussel beds as are found in shallow water. It seems in general to prefer mud to sand and gravel, and the percentage collected depends much upon the methods of collecting. Work in deep water will bring to light a larger percentage than wading or gathering by hand or a rake.

The breeding season in the Cumberland begins in May and extends through the greater part of June, perhaps longer. In this species the condition of the development of the young can be roughly estimated by the appearance of the gill. When the ova pass down into the gill they are at first red, or carmine, probably because of an abundance of food material; as the glochidia develop they gradually fade out until the gills of a fully ripe niggerhead are of a dirty white color.

There is not much variation in shape among the shells, some being elongate and others more rounded than the average. The shells show very little erosion, and the young exhibit the peculiar white patch near the umbone, as has been fully described by Lea. The nacre is rather frequently stained brown, and nearly all lack uniformity in thickness, the shell thinning out somewhat abruptly a little behind the middle of

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[a] Conrad, Monograph, p. 41, pl. xx.

the ventral margin, leaving thin tips. The shell is easily distinguished from any other species in the river except from old examples of *Q. subrotunda,* which are always more elongate and always have yellow flesh.

Q. ebena would probably thrive only in the lower parts of the river, although when the propagation of this species becomes feasible it may be worth trying in the upper river.

78. *Quadrula tuberculata* Rafinesque. Purple warty-back.

A careful study of our material, as well as of the evidence at hand from the literature, convinces us that *Q. granifera* and *Q. tuberculata,* though quite markedly distinct in typical cases, are really connected by intermediate forms. In some rivers, like the Tippecanoe at Delong, Ind., only strongly marked *tuberculata* are found. In others, like the Mississippi about Fairport, Iowa, only well-marked *granifera* are found. In such streams or portions of streams as contain both species they are indistinguishable, or so connected by intergrades that no clear line of demarcation can be drawn between them. In the Cumberland, the first shells seen, in the lower part of the river, were identified provisionally as *granifera;* as we ascended the river some doubts as to the species began to appear, while in the upper tributaries the shells were pretty clearly identified as *tuberculata.* This naturally introduces the question as to influence of environment on shell form, which may be touched upon briefly here.

The most striking and essential difference between *tuberculata* and *granifera* is one of degree of inflation, *tuberculata* being a flat form and *granifera* much inflated. We have a number of cases among the Unionidæ where two otherwise similar shells are distinguished by this feature; among these are: *Q. plicata,* inflated, *Q. undulata,* compressed; *D. dromas,* inflated, *D. caperatus,* compressed. From our experience we are inclined to believe that one usually finds the compressed species in small streams, while the more inflated forms are found in large rivers. Often when a main stream has *plicata,* the little tributaries will have *undulata,* especially if they are rather shallow and swift streams with gravel bottoms. The more compressed form is better adapted to plow into the gravel or crawl under rocks and hold its position in a swift current, where the inflated form would present too much surface to the force of the water. In the softer mud and weaker current of larger streams an inflated form would be advantageous, helping to buoy up the animal.

To state the situation precisely as we have found it, if one takes one of the larger rivers from source to mouth, and finds both *tuberculata* and *granifera* or *plicata* and *undulata* in the stream, the compressed form is likely to be in the upper stretches of the river while it is a small swift stream, and the more inflated form farther down in the main body of the river where the bottom contains more mud and the current is slower. Extreme forms of either species, so far as we know, are never found in the same bed, but where both are represented the forms run together.

The literature relating to *granifera* and *tuberculata* is exceedingly interesting, but too long to give in detail. To understand the present status of the group, however, it is necessary to state that Simpson in his Synopsis removed these two species from the *Quadrula pustulosa* group, where they had been previously placed, making of them the subgenus *Rotundaria* on the basis of a "well-developed sulcus on the posterior slope and remarkable beak sculpture." The beak sculpture is well marked on *tuberculata* but not so well, or almost absent, on *granifera.* Ortmann, finding only the outer gills used as marsupia in *tuberculata,* raised *Rotundaria* to generic rank. We have usually found only the outer gills of *granifera* at Fairport marsupial, although we have a record of one example with marsupia in all four gills.

The species does not reach a very large size in the Cumberland. On account of its purple nacre it is of no value for buttons.

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